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Solar Physics, Astrophysics, and Astronomy

7730 Gamma ray astronomy
SAS-2 OBSERVATIONS OF THE EARTH ALBEDO GAMMA RADIATION ABOVE 35 MeV
D. J. Thompson (Code 662, NASA Goddard Space Flight Center, Greenbelt, MD 20771) G. A. Simpson and M. E. Ozel

Observations with the SAS-2 high energy γ-ray telescope have been used in a study of the earth albedo γ radiation above 35 MeV in the equatorial region. The γ-ray intensity has a peak toward the horizon which is about two orders of magnitude more intense than the cosmic γ radiation from most parts of the sky. The radiation from the western horizon is about four times as intense as the radiation from the eastern horizon and about three times as intense as that from the northern or southern directions. The energy spectrum of the radiation from the horizon is flatter than that from the nadir. (Gamma rays, atmosphere, cosmic rays).
J. Geophys. Res., Blue, Paper 80A1520

Tectonophysics

8150 Plate tectonics
THE ICELAND RESEARCH DRILLING PROJECT
I.B. Fridleifsson, Ian L. Gibson, J.M. Hall (Dept. of Geology, Dalhousie University, Halifax, N.S., Canada B3H 3J5), H.P. Johnson, N.I. Christensen, Hans-Ulrich Schmincke and Gunther Schönharting

This paper forms the introduction to an issue of the Journal of Geophysical Research devoted to the collected results of studies on a 3 km vertical section of Icelandic crust by an international group drawn from Iceland, Canada, U.S.A., U.K., West Germany and Denmark.
J. Geophys. Res., Red, Paper 1B0460

8150 Plate tectonics
GEOID ANOMALIES IN THE VICINITY OF SUBDUCTION ZONES
David C. McAdoo (Geodynamics Branch, Goddard Space Flight Center, Greenbelt, Maryland 20771)

The regional geoid of the southwest Pacific is matched reasonably well by results from a model of the upper mantle density structure (including slabs) associated with subduction zones of the region. Estimates of the geoid are obtained from Geos-3 and Seasat radar altimeter data. These data are very well suited to the task of detecting intermediate wavelength (800-4000 km) geopotential variations, which contain the dominant signature of subducting slabs. Gravimetric profiles across trench-island arc complexes resolve primarily short wavelengths. The model represents subducting slabs as thin surfaces of anomalous mass per unit area. These surfaces are positioned using published seismicity results which detail the configuration of the Benioff zones. Crustal effects are ignored. Effects due to the contrast between the young thermal lithosphere of the behind-arc regions (marginal basins) and the older lithosphere seaward of the trench are modeled. Results indicate that the New Hebrides slab possesses an average areal density anomaly of about 3×10^3 gm cm^{-2}. This is about three times that which is estimated for the Tonga-Kermadec slab. Both of these inferred density anomalies are somewhat less (~10% and 65%) than anomalies predicted by a thermal model. Consistent with the results of other studies, additional modeling suggests that slabs worldwide may be an important source of large, long wavelength gravity highs: i.e., they may contribute substantially to geopotential power of harmonic degree as low as three or four. (Subduction, geoid anomalies, slab, lithosphere).
J. Geophys. Res., Red, Paper 1B0409

8150 Plate tectonics
PALEOMAGNETISM AND MESOZOIC-CENOZOIC PALEOCONTINENTAL MAPS
J.C.Briden (Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, England) A.M.Hurley and A.G. Smith

A method of making paleocontinental reconstructions based on ocean-floor magnetic anomaly data and land-based paleomagnetic data is briefly described and its limitations assessed. Synthetic polar wander paths for the period 20-200 Ma are presented for Australia, Antarctica, India, Africa, Eurasia, North America and South America. Comparison is made with observed paths, except for Antarctica, for which the data are too sparse. There are no significant differences between observed and synthetic paths. A plot of inclination anomaly against paleolatitude shows a large scatter that limits the precision of the paleographic grid on continental reassemblies. The absence of any systematic trend to this scatter with time suggests that the field has had the same average behaviour over the past 180 Ma and that large-scale expansion of the Earth cannot have occurred in this period. South America has undergone the least change in position relative to the poles in the past 100 Ma. (Paleocontinental maps).
J. Geophys. Res., Red, Paper 1B0459

Volcanology

8499 Volcanology
MODELING THE THREE-DIMENSIONAL STRUCTURE OF MACROSCOPIC MAGMA TRANSPORT SYSTEMS: APPLICATION TO KILAUEA VOLCANO, HAWAII
Michael Ryan (Department of Mineral Sciences, Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560), Robert Y. Koyanagi and Richard S. Fiske

We report the results of modeling the three-dimensional internal structure of Kilauea's magmatic passageways. The approach uses a clear plexiglass model containing equally-spaced levels upon which well-located seismic hypocenters are plotted. Application of constraining geologic and geophysical criteria to this distributed volume of earthquakes permits the interpretation of seismic structures produced by fracturing in response to locally high fluid pressures. The following magma transport and storage structures have been identified within and beneath Kilauea:

Primary conduit. The conduit transporting magma into Kilauea's summit storage reservoir rises from the model base (14.6 km) to the 6.5 km depth level. It is a zone of intense fracturing and inferred intrusion, whose horizontal sections are elliptical in planform. Over its height, the average major axis of the component horizontal sections is 3.3 km, with an average minor axis of 1.7 km. This yields an aspect ratio of ξ = 0.52. At the 14.6 km level, the strike of the major axis is N 67°E. During passage from the upper mantle through the oceanic crust, this axis rotates in a right-handed sense, until the strike is N 41°W at the 6.5 km level.

Magma chamber complex floor. The interval from 6.5 to 5.7 km, immediately over the primary conduit, is aseismic. This suggests differentially high fluid-to-rock ratios, and relatively weak pathways for further vertical transport into higher levels of the storage complex as well as lateral leakage eastward into the Mauna Ulu staging area—for later vertical ascent beneath the upper east rift zone. Seismicity within the immediately subjacent rocks that form the top of the primary conduit (at 6.5 km) suggests that this inferred magma-rich horizon forms the effective floor of the summit storage complex.

Magma chamber crown. Intense seismicity over the 1.1-2.6 km depth interval defines an elliptical region in plan view. The top of this region has a broad apex with an average major axis of 1.5 km, and an average minor axis of 1.1 km, producing an aspect ratio of ξ = 0.73. This region coincides with the epicentral position of summit vertical displacement maxima during inflationary deformation and is interpreted as a region of intense diking, crowning the summit storage complex.

Upper east rift zone pipe. From a depth of 5.7 km, a cylindrical region of seismicity rises beneath the upper east rift zone, to the 1.9 km level, where it merges with the subhorizontal upper east rift zone duct. This pipe-like zone has a mean diameter of 1.4 km and a vertical axis that pierces the surface of the volcano at the intersection of the Koae fracture system and the upper east rift zone. We suggest this pipe forms a principal connection between the base of the summit storage reservoir, and near-surface storage compartments and ducts in the upper east rift zone. In this role, the pipe is suggested to have contributed heavily to Mauna Ulu's magma supply during 1969-1974.

The model of magma transport and storage thus constructed provides a context in which other types of data (e.g., ground deformation and electrical conductivity) may be interpreted as well as a means of refining petrological inferences based on lava chemistry. (Volcanic conduits, magma transport, Kilauea).
J. Geophys. Res., Red, Paper 1B0407

General or Miscellaneous

9820 New Fields
AQUIFER THERMAL ENERGY STORAGE-A NUMERICAL SIMULATION OF AUBURN UNIVERSITY FIELD EXPERIMENTS
Chin Fu Tsang (Lawrence Berkeley Laboratory, Earth Sciences Division, Berkeley, CA 94720) Thomas Buscheck, Christine Doughty

This paper describes the computer simulation of two cycles of a seasonal aquifer thermal energy storage experiment recently carried out by Auburn University. The simulated production temperatures and energy recovery factors agree very well with the field data. A general description of the experiments and the numerical model used are given. Discussions are also given on the determination and choice of various parameters used in the simulations. These are followed by a detailed comparison of simulated and observed temperature distributions.
Water Resour. Res., Paper 80W1808

Editorial

Proposed New Journal: *Tectonics*

There is a fundamental and urgent need for a high-quality international journal in tectonics. The literature is growing rapidly, and the best papers are spread through a wide range of journals such as *Journal of Geology*, Red JGR, *Tectonophysics, GSA Bulletin*, EPSL, *Geological Magazine, Geology, Geophysical Journal of the Royal Astronomical Society, Geological Society of London Journal*, and *American Journal of Science*. A top-flight international journal in tectonics with the highest refereeing standards would attract the very best papers and would rapidly gain acceptance as the prestige place to publish the best in analytical, synthetic, and integrative tectonics. It would be a journal to be read by almost everybody in regional geology, structure, tectonics, geophysics and hard-rock geology. Care would be needed to ensure that it did not harm the red JGR or GRL, which could be accomplished by defining the goals of the new journal so that everyone understood the kind of papers that would be considered. This could and should be done by excluding short notes and restricting papers for the new journal to the field of tectonics sensu-stricto, i.e., the structure and evolution of the terrestrial lithosphere, with dominant emphasis on the continents. Papers on mantle convection, tidal friction, solid earth seismology, mantle and core petrology, and origin of the earth's magnetic field, for example, would thus be excluded. One could have the journal lean very heavily though not exclusively toward the structure and evolution of the continental lithosphere (dominantly the continental crust) and give the journal a strong slant toward integrative tectonics, structural geology, and materials science but discourage, for example, rock mechanics and earthquake prediction, which would go to the red JGR. I thus visualize a more continental, more geological, and less geophysical emphasis in a journal of tectonics. There would be some overlap with the red JGR but not a great deal. In no sense would this be a letters journal, competing with GRL. We have a superb opportunity to found a scholastically excellent journal that is really needed in earth science. Tectonics is one of the central cores of earth science today, and yet we do not have a journal devoted exclusively to it.

John F. Dewey
State University of New York at Albany

Comments Requested.

The Publications Committee solicits your comments and suggestions on the proposed new journal described above by Professor Dewey. According to present plans, AGU could publish this journal on a bimonthly schedule at a subscription price to AGU members of \$15–\$20 per year. In order to hold subscription prices down the journal would be limited to the equivalent of 400 JGR pages per year, but it would probably appear in a page size smaller than that of JGR. A high rate of rejection of manuscripts might be needed to limit the size of the journal while maintaining reasonably rapid publication. There would be no page charges, but only author-produced copy would be published. As is the case for author-produced papers in other AGU journals, papers would be copy edited before authors prepared camera-ready copy.

The Publications Committee feels that this proposed journal is scientifically worthwhile, is targeted on a rapidly growing field that lacks a publication focus, and will probably be a great success. More generally, we believe that geophysicists may welcome inexpensive, multidisciplinary journals oriented toward particular areas of research.

Please send your comments and suggestions to me at

Space Physics Research Laboratory
The University of Michigan
Ann Arbor, Michigan 48109

James C. G. Walker
Chairman, Publications Committee

Cover. A view of the Inner Harbor, one of the major attractions in Baltimore, host city for the 1981 AGU Spring Meeting.

Nd Isotopic Studies: Some New Perspectives on Earth Structure and Evolution

Donald J. DePaolo

Department of Earth and Space Sciences
University of California, Los Angeles

This article is the text of a talk presented in the Frontiers of Geophysics session at the 1980 AGU Spring Meeting in Toronto, Canada.

Introduction

Geochronology is generally regarded as a branch of geochemistry that focuses on the determination of the ages of rocks. Although the reliable determination of ages of rocks is no trivial task, the above definition of geochronology is overly restrictive because the long-lived radioactive nuclides that can reveal the age of rocks can also yield a unique type of information about the internal structure of planets and the processes by which that structure is formed. In the case of the earth and the terrestrial planets, the internal structure can be described grossly by the division into core, mantle, crust, and an atmosphere-hydrosphere system where present. The present state of the earth (moon, Mars, etc.) can be studied by a number of methods, including photogeologic, petrologic, and chemical characterization of crustal rocks, and geophysical studies of the interior through the use of seismicity, gravity, heat flow, and other methods. But when and how this structure formed cannot generally be ascertained by those methods except by inference from theoretical models. The time dimension is uniquely accessible through the study of variations in the natural abundances of radioactive elements and their decay products, i.e., through geochronology. By using information about the geochemical properties of the elements, coupled with the measured isotopic variations, the nature of planetary differentiation processes and the associated time scales can be inferred. Such information is critical for linking what is known about the present structure of the earth to models of its evolution over the past 4.5 billion years. There is, however, an important restriction to the applicability of isotopic measurements, and that is that only if the geochemical properties of the particular elements are well understood can isotope abundance variations caused by radioactive decay be translated into information on planetary evolution.

For this reason there was great excitement when, in 1974 and 1975, Günther Lugmair, Kurt Marti, and Norman Scheinin of the University of California, San Diego, chemistry department were able to determine the age of the basaltic meteorite Juvinas and a lunar basalt, using the decay of Samarium-147 (^{147}Sm; half life = 106 eons) to Neodymium-143 (^{143}Nd) [*Lugmair et al.*, 1974, 1975]. The excitement stemmed from the fact that these two elements, Sm and Nd, were rare-earth elements (REE), and this group of elements, found in trace amounts in all rocks and minerals, has been the subject of intensive study over the past two decades, beginning with the pioneering studies by Roman Schmitt, Lawrence Haskin, and coworkers [*Haskin et al.*, 1966] and continuing with increasing sophistication to the present (rare-earth geochemistry has recently been reviewed by *Haskin and Paster* [1979]). Presently the REE are by far the best understood trace elements in terms of their behavior in planetary processes. In addition to being well understood, Sm and Nd also have properties that are much different from the parent-daughter element pairs that had been previously used in geochronology, mainly U-Pb, Th-Pb, and Rb-Sr. They therefore promised to give an entirely new perspective on earth evolution. Shortly after the work of the UCSD group, the system was applied to terrestrial rocks [*DePaolo and Wasserburg*, 1976a, b; *Richard et al.*, 1976; *O'Nions et al.*, 1977] and has yielded a large number of exciting results. The purpose of this article is to briefly describe the most important findings of these studies to date, and their implications for models of the structure and evolution of the earth's mantle and crust. It should be noted that the Sm-Nd system is the first geochronometer to come into use when the geochemistry of the parent and daughter were already well known. This facilitated its immediate use as a geochemical tracer rather than purely as a tool for determining the age of rocks. Sm-Nd also represents an excellent example of a method originally developed for studies of lunar rocks that has paid great dividends in terrestrial applications.

The Isotopic Record of Planetary Evolution

The uniqueness of the information yielded by Sm-Nd isotope studies can be understood by considering the differences between Sm-Nd and the various other geochronometers. One of the more important differences is illustrated in Figure 1. The time axis in each graph is age; that is, time measured backwards from the present. The vertical axis is the ratio of the radiogenic isotope to another isotope of the same element that is neither radiogenic nor radioactive, the latter being used as a normalizing abundance. These ratios increase with time as the radiogenic isotope accumulates from the decay of the parent. The rate at which the ratio increases in a given environment is proportional to the abundance of the radioactive parent relative to the normalizing isotope of the daughter element (referred to as the parent/daughter ratio). Changes in the slopes of these evolution lines are therefore related to chemical fractionation of the parent and daughter elements. Although not the primary subject of this article, a good example of how the isotopes track earth evolution is the U-Pb system (Figure 1). The isotope ^{206}Pb is the product of ^{238}U decay, so the slope of an evolution line on Figure 1 (bottom) is proportional to ^{238}U/^{204}Pb. This ratio is known to have been very small in the solar nebula, as evidenced by the present solar abundances, so the evolution curve shown for the nebula (labeled SN) has a small slope. As the nebula condensed, U—which has a high condensation temperature—probably condensed earlier than Pb, which has a low condensation temperature. If the earth accreted before all of the Pb condensed, or if Pb was lost by volatilization during accretion, then the earth would have formed with a U/Pb ratio higher than that of the SN when it accreted ~4.5 eons ago. This is shown on Figure 1 (bottom) by the increased slope of the earth curve, following condensation and accretion (CA).

Further fractionation of U from Pb could have occurred in the earth as a result of core formation (CF), because the tendency for Pb to occur as a sulfide could have resulted in its entering the core in large amounts, while U would have been excluded from the core. The result: a high U/Pb silicate portion of the earth (mantle and crust) and a low U/Pb core. Subsequent to core formation, magmatic processes in the silicate portion can cause formation of domains of somewhat higher and lower U/Pb to form, shown by the diverging arrows. The present average values of ^{206}Pb/^{204}Pb found in the earth's crust (C) and upper mantle (UM) and their relationship to the value for the total earth (⊕) and the sun are shown on the $T = 0$ axis of the graph. (Note that the earth value is actually unknown because the changes in U/Pb that are caused by core formation as opposed to condensation and accretion are not known.) The kinks in the curves, corresponding to changes in U/Pb, are the times that are recorded with most sensitivity. Thus the U-Pb system gives very precise information on the time of formation of the earth and/or core formation but is less sensitive to the time of separation of the crust from the mantle because little change in U/Pb is involved in the latter process. In fact, the U/Pb system yielded the first accurate estimate of the age of the earth, as well as the most precise estimate available today. The situation for Rb-Sr is somewhat different (Figure 1 (middle)). Rb is substantially more volatile than Sr under the conditions that prevailed in the SN, and the earth apparently inherited a Rb/Sr ratio about 10 times smaller than the sun's. But fractionation during core formation is less likely, so Rb-Sr precisely fixes the

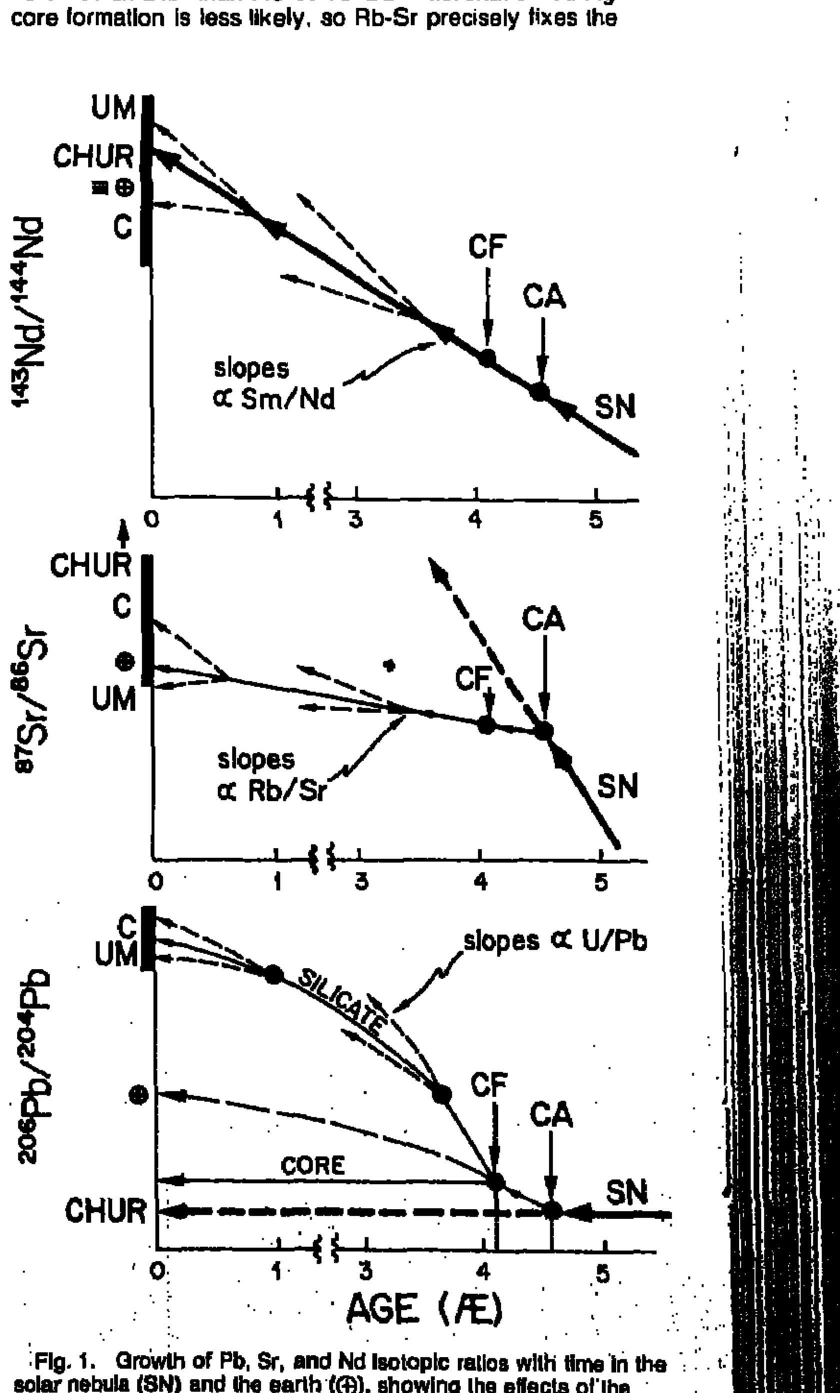

Fig. 1. Growth of Pb, Sr, and Nd isotopic ratios with time in the solar nebula (SN) and the earth (⊕), showing the effects of the original condensation of the nebula and accretion of solid bodies (CA), core formation in the earth (CF), and subsequent magmatic processes within the earth. On the $T = 0$ axis are shown the relative present-day values of the isotopic ratios for the earth's upper mantle (UM) and continental crust (C) and their relationship to the values in the earth, sun (SN), and the chondritic meteorites (Chur). Only for Nd do the present values for the earth, sun, and chondrites correspond. Nd isotopic variations measured in rocks therefore reflect only the magmatic processes that have caused the earth to evolve the present structure of its mantle and crust.

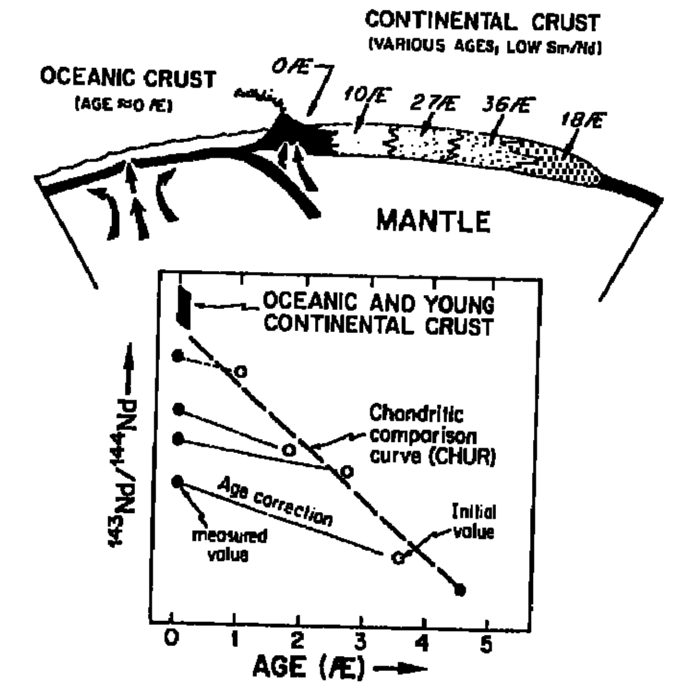

Fig. 2. The evolution of the $^{143}Nd/^{144}Nd$ ratio in the earth's mantle is determined by measuring the present-day value of $^{143}Nd/^{144}Nd$ in rocks from the crust and correcting for the rock's age, which also must be determined. Initial ratios, calculated for rocks of various ages, are used to define the $^{143}Nd/^{144}Nd$ in the mantle as a function of time. By comparing those to the chondritic meteorite curve (Chur), information is obtained about the evolution of mantle structure through time.

time of the earth's formation. Subsequent magmatic processes have also fractionated Rb and Sr by large factors, so that information on the age of the crust is also given by Rb-Sr. The present $^{87}Sr/^{86}Sr$ of crust and upper mantle presumably straddle the earth value, but the exact earth value is unknown because essentially all materials at the earth's surface have been affected by magmatic fractionations at some time. The evolution curves for $^{87}Sr/^{86}Sr$ are almost straight lines because the half-life of ^{87}Rb is so long (50 eons ≈ 50×10^9 yr).

The Sm-Nd system is different because both Sm and Nd probably condensed from the solar nebula at the same time, and neither would have entered the core, so there was no fractionation of Sm from Nd at those times. However, substantial fractionation of Sm from Nd does occur in magmatic processes, and essentially only in magmatic processes. Consequently, the Sm-Nd system gives no information on the age of the earth, but, on the other hand, it provides an excellent means to study the magmatic differentiation of the planet without complications that relate to its original formation. A good estimate of the present-day $^{143}Nd/^{144}Nd$ for the total earth is provided by measurements on the chondritic meteorites [*Jacobsen and Wasserburg*, 1980]. This baseline value is enormously valuable. For instance, the complementary nature of the present-day $^{143}Nd/^{144}Nd$ values for the earth's upper mantle and continental crust is readily apparent in Figure 1 (top). Estimates of the amount of Nd present in each reservoir have therefore allowed a mass balance between the crust and the mantle, simply using the lever rule, so that the amount of the mantle that has been involved in producing the crust

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could be calculated (see below). The Sm-Nd method adds a new, and much needed, dimension to isotopic studies of planetary evolution.

The Evolution of the Earth's Mantle

The application of the Sm-Nd method to problems of the history and structure of the earth's mantle is illustrated in Figure 2. Measurements of the $^{143}Nd/^{144}Nd$ ratio in oceanic volcanic rocks, all of which are relatively young in comparison with the age of the earth, and in young continental rocks give an indication of the value and the variability of this ratio in the upper mantle today because the rocks represent solidified magmas that are presently coming from the upper mantle. Older rocks are present in the continental crust, and can be used to determine the $^{143}Nd/^{144}Nd$ in the mantle at various times in the past. The assumption is that all of the rock materials that make up the continents were, at one time, derived from the mantle as magmas, which solidified and have remained near the surface because of their low density. As shown in Figure 2 (bottom) the $^{143}Nd/^{144}Nd$ ratio is measured in a rock sample and then corrected for the rock's age back to an 'initial' value which represents the $^{143}Nd/^{144}Nd$ ratio the rock had at the time it came from the mantle. The slope of the age-correction vector is proportional to the Sm/Nd ratio measured in the rock, as in Figure 1. The initial ratios can then be compared to the $^{143}Nd/^{144}Nd$ growth in a chondritic environment (called 'CHUR' for chondritic uniform reservoir). Deviations from this curve, usually expressed as the parameter ε_{Nd} (in units of 0.01%), are indicative of chemical differentiation in the mantle and can be interpreted in terms of models of earth evolution. Recovering information about the mantle from rocks in the continental crust can be a tricky business and requires a considerable amount of geological insight, which comes from other types of studies of the rocks. A particular problem is that some igneous rocks do not represent magmas derived from the mantle but, rather, appear to be melted from the crust itself. Such rocks can give no information about the mantle. On the other hand, the $^{143}Nd/^{144}Nd$ initial ratios can often be used to identify magmas derived from the crust, a problem of considerable interest, especially for some magmas that contain economically important amounts of ore metals such as gold, silver, copper, and molybdenum.

Initial $^{143}Nd/^{144}Nd$ ratios that have been determined on rocks which are suspected of being derived from the mantle are shown on Figure 3. The most obvious conclusion is that the data fit the CHUR curve rather well. This indicates that the Sm/Nd ratio of the mantle, and presumably the whole earth, is essentially exactly that of the average chondritic meteorite, where 'exactly' means ±2% or 3%. The demonstration of such a close correspondence between the relative abundance of two elements in the earth and chondrites is unprecedented and offers support that chondrites provide a meaningful model for the earth's composition, at least for some elements that are nonvolatile and nonmetallic in their geochemical behavior.

The minimal scatter about the CHUR line, especially for rocks older than about 2 eons, is also noteworthy. It indicates that the mantle started out with a uniform composition, probably because of the mixing effect of rapid convection when the earth was hotter, during its early history. The uniformity contrasts sharply with the pronounced layering in the moon evidenced by analogous data from lunar rocks (Figure 8). Younger rocks exhibit increasing scatter, mostly above the CHUR line, indicating that chemically different domains evolved gradually in the mantle as opposed to being formed early and persisting through time.

The Age of the Continents

When continental crust forms, it generally is fractionated chemically, relative to the mantle, including having a Sm/Nd ratio about 40% lower on average. Consequently, its subsequent isotopic evolution is along a vector of proportionally lower slope, as shown in Figure 3 for crust formed 3.6 eons ago. In cases where crustal age was not previously known, the intersection of the crust evolution vector with the CHUR curve gives the age. This model age is called T_{CHUR}. Interestingly, no rocks have yet been found with intersections that correspond to an age greater than 3.8 eons. Thus the oldest rocks known are about 0.75 eons younger than the age of the earth. The Sm-Nd data confirm that this age gap is real and not merely the effect of 'resetting' of isotopic ages at more recent times, which can

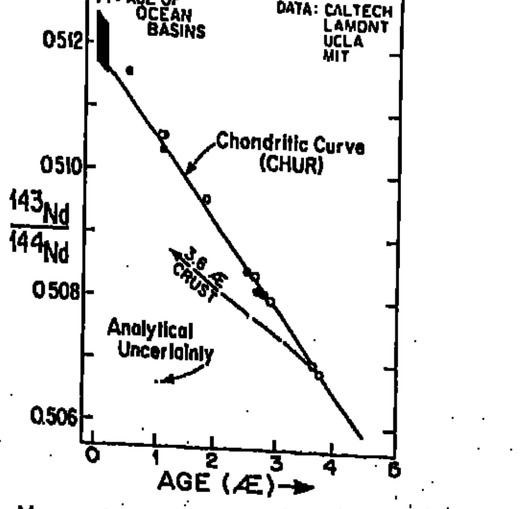

Fig. 3. Measured initial ratios for crustal rocks, showing a close fit to the Chur curve, with increasing scatter at more recent times. Note that the total change in $^{143}Nd/^{144}Nd$ over the entire history of the earth is only about 1%, but the analytical uncertainty is still small by comparison.

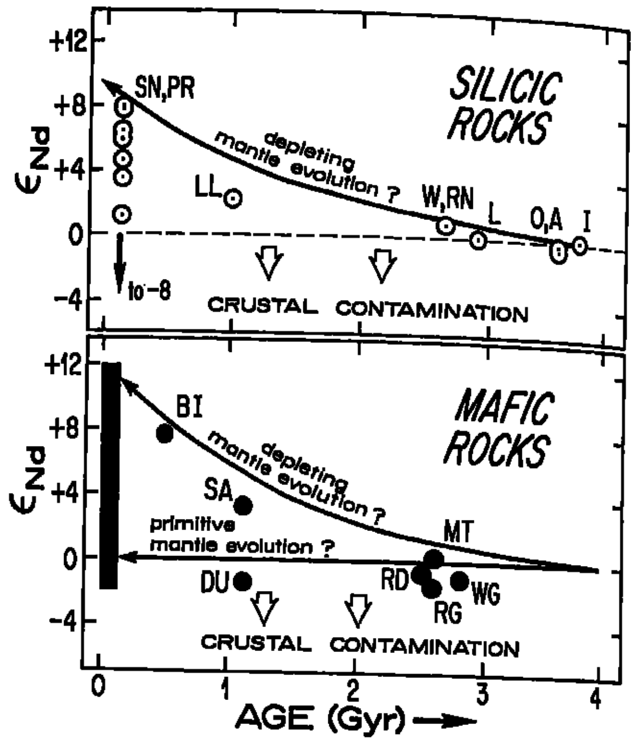

Fig. 4. Deviations of the initial $^{143}Nd/^{144}Nd$ ratios from the Chur curve (from Figure 3), expressed as ε_{Nd}—the fractional difference in units of 0.01%.

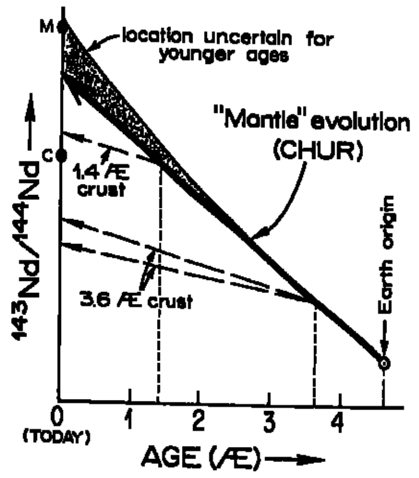

Fig. 5. Model for crust and mantle Nd isotopic evolution. Crust forms by extraction of chemically fractionated material from the mantle and evolves along lines of lower slope, reflecting low Sm/Nd ratios. The residual mantle, with increased Sm/Nd, must evolve away from CHUR in the opposite direction. Present values of $^{143}Nd/^{144}Nd$ in average crust (C) and in midocean ridge basalts (M) are also shown.

sometimes obscure the true age. T_{CHUR} ages are not sensitive to later tectonic disturbances, as are many other radiometric ages. The explanation of this delay in the formation of crust is still not agreed upon. Presently favored is the idea that the early earth was so hot, and convection so rapid, that crust was unstable, being destroyed and remixed into the mantle as rapidly as it formed. Only after the earth cooled sufficiently could crust be preserved. An alternative hypothesis that the earth started cold and required time to heat up to the point that melting could occur in the interior and crust formation begin is considered less likely.

The deviations of the data points from the CHUR curve are magnified in the ε_{Nd}-time diagrams of Figure 4. The increasing deviations at more recent times are clearly shown. The mafic rocks, basalt and gabbro, have petrologic characteristics that are consistent with their coming directly from the mantle as magmas. They could be considered the best samplers of the mantle. On the other hand, the silicic rocks, granite, granodiorite, and related rock types, have petrologic characteristics that suggest they are not directly derived from the mantle. However, silicic rocks appear to make up the bulk of the continental crust and are therefore important for determining how crust is formed. If the mantle had retained a chondritic Sm/Nd ratio throughout the earth's history, all of the points would be expected to fall at $\varepsilon_{Nd} = 0$ for all times. The deviations from $\varepsilon_{Nd} = 0$ indicate that at least some parts of the mantle have acquired an Sm/Nd ratio different from chondritic. Since most of the deviations are positive (i.e., $\varepsilon_{Nd} > 0$), the implication is that parts of the mantle have Sm/Nd higher than chondritic.

A simple explanation emerges if one recalls that the continental crust has low Sm/Nd. It is also enriched in both elements, relative to the mantle, by a factor of about 25 for Nd and about 16 for Sm. Consequently, it is clear that as continental crust forms the mantle loses Nd at a greater rate than Sm and hence acquires a higher Sm/Nd ratio. The curved lines in Figure 4 show how the ε_{Nd} of the mantle would evolve as its Sm/Nd gradually increased as a result of the growth of the crust. The overall model is illustrated in Figure 5, where the complementary nature of the crustal evolution lines for $^{143}Nd/^{144}Nd$ (dashed) and the mantle evolution (shaded) is shown. This model for the relationship between the chemical composition of the crust and complementary changes in the composition of the mantle is intuitively simple and, in fact, seems almost trivial. But, surprisingly perhaps, this consideration had until recently received relatively little attention, for the reason that with the other isotope systems the complementary changes in the mantle could not be identified because the starting-point composition was unknown (as shown in Figure 1). The Sm-Nd isotope system provides the baseline—the $\varepsilon_{Nd} = 0$ line (CHUR), and the systematic deviations shown in Figures 4 and 5 represent the first data that can be used to quantify the complementary nature of the continental crust and the mantle from which it was extracted. Furthermore, the isotopes are better tracers for this purpose than chemical traits, because they are intensive and see through the chemical changes that accompany the formation of magma in the mantle.

Basaltic Volcanism and a Model for the Structure of the Mantle

The ε_{Nd}-time data are one side of the evidence that has led to a rather simple picture of the structure of the mantle and its relationship to the crust, depicted in Figure 7. The other side is shown in Figure 6, a histogram of ε_{Nd} values measured in young basalts. This figure shows the distribution of some of the data within the heavy solid bar in Figure 4 (bottom). The important characteristics of the data are: (1) basalts (or andesites) of a given tectonic setting have a characteristic value of ε_{Nd}, with a finite variability of about ±2 or 3 units, (2) almost all oceanic basalts have ε_{Nd} between +4 and +12, and (3) continental flood basalts, volumetrically the most significant manifestations of basaltic volcanism on continents, have ε_{Nd} distinctly different from the oceanic basalts and cluster at $\varepsilon_{Nd} \approx 0$, the value characteristic of undifferentiated mantle. Taking these values to represent the ε_{Nd} of the mantle domains from which the basalts come, the oceanic lavas clearly show the depleted (in Nd relative to Sm) nature of the mantle, as expected. The continental lavas, however, appear to require that some parts of the mantle are still in a relatively pristine state and have not been affected by extraction of continental crust. Furthrmore, there is simply the puzzling difference between continental and oceanic regions, independent of the meaning of the actual values.

One of the most interesting aspects of these data is the relatively tight clustering of ε_{Nd} values for each group, even though the points represent a worldwide sampling. This indicates, for instance, that the mantle 'reservoir' from which midocean ridge basalts come is relatively well mixed on a global scale—and on a time scale that is short in comparison with the age of the crust. This also appears to hold true for island arcs and intraplate oceanic islands, even though each has a mean ε_{Nd} that differs from the rocks of the other tectonic settings. Clearly, these observations must be taken into account in any model of the structure and dynamics of the earth's mantle. However, at the present state of knowledge it is far from clear how best to model the data.

Wasserburg and DePaolo [1979] took a geometrical approach, visualizing the earth as a series of boxes, each with a characteristic ε_{Nd} and each representing a possible source for basalt magmas. These boxes then had to be arranged in a way so as to produce the observed distribution of ε_{Nd} values at the surface (Figure 7) and still be reconcilable with continental drift and plate tectonics. For example, one of the 'rules' used in constructing the model was that magmas erupted on continents must always be different isotopically from those erupted in oceanic areas, but, in addition, continents and oceans must be allowed to change places almost instantaneously as a result of continental drift. The complementary nature of the continental crust and the upper (oceanic) mantle had also to be taken into account.

The resultant model, in a simplified form, is shown in Figure 7. Basically, it is a two-layer mantle. The lower mantle is undifferentiated with respect to Sm, Nd, and other lithophile elements and, consequently, has retained its $\varepsilon_{Nd} = 0$ for the entire history of the earth. The upper mantle continuously cycles through the process of ocean floor formation at ocean ridges and subduction, and, as a by-product of this cycle, new continental crust is continually made in magmatic arcs associated with the subduction zones by extraction of chemically fractionated materials from the mantle. The upper mantle today therefore has a positive ε_{Nd} (+12), which represents the integrated effect of making low-Sm/Nd crust over the past 3.8 eons. This positive ε_{Nd} is counterbalanced by the negative-ε_{Nd} continental crust, estimated to average $\varepsilon_{Nd} \approx -15$. (The estimated average values of $^{143}Nd/^{144}Nd$ in the crust and upper mantle are shown schematically in Figure 5, where the relationship of the average crustal $^{143}Nd/^{144}Nd$ to the average age of the

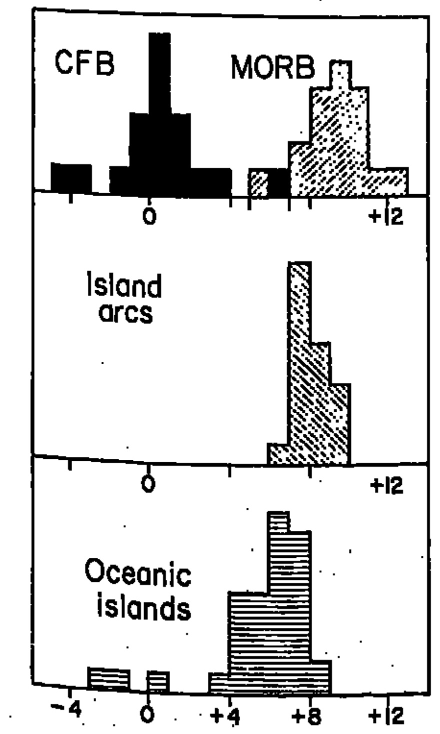

Fig. 6. ε_{Nd} values in young basalts. MORB—midocean ridge basalt, CFB—continental flood basalt (from *DePaolo and Wasserburg*, 1979a).

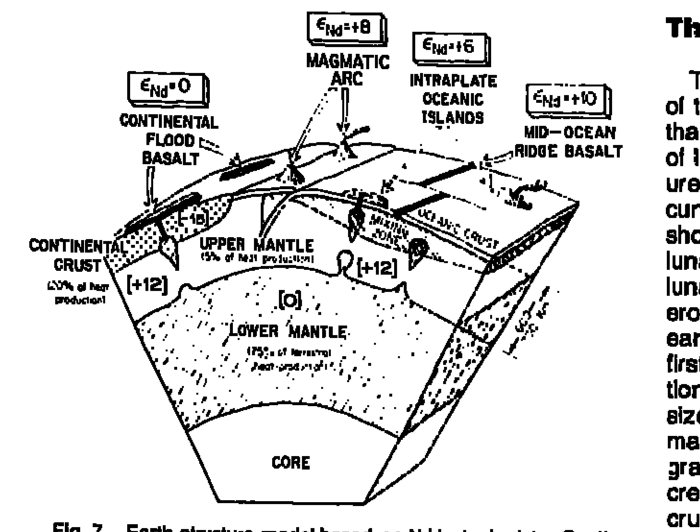

Fig. 7. Earth structure model based on Nd isotopic data. Continental crust is continuously produced in magmatic arcs from the upper mantle, and presently the ε_{Nd} values for the crust (−15) and the upper mantle (+12) are complementary. The lower mantle does not directly take part in the crust-producing process, but diapirs or plumes rise up from the lower mantle, producing intraplate basaltic volcanism and releasing juvenile gases to the atmosphere. The depth shown for the upper-lower mantle boundary is a best estimate; the data would allow it to be either shallower or deeper.

crust is apparent.) Since the mass of the continental crust is known to be about 2×10^{25} g, the ε_{Nd}'s can be used to estimate the size (thickness) of the 'upper mantle' pictured in the model. The crust has a Nd abundance estimated to be about 50–60 times higher than the present upper mantle (which is depleted as a result of crust formation), hence the mass of the upper mantle is calculated to be about 100×10^{25} g. This corresponds to a thickness of about 600–700 km; only about one fourth of the mass of the whole mantle. Coincidentally, the calculated depth range corresponds to a marked seismic velocity discontinuity. This finding supports the suggestion that the seismic structure of the mantle may be related to chemical composition differences, and offers a possible explanation of the evolution of this structure. The various intermediate values of ε_{Nd} found in the oceanic basalts are explained in this model as mixtures of materials from the two mantle layers. Mixing occurs to a great extent in oceanic regions because of the presence of a shallow highly fluid zone where the mantle is near (or above) its melting temperature (low-velocity zone) but generally does not occur in continental areas where this fluid zone is weakly developed or absent entirely.

This view of the earth is attractive for several reasons. It is simple and yet can explain a large fraction of the observations, both isotopic and chemical. In addition, it adds a time perspective to the development of the layering in the mantle. An important implication of the model is that the radioactive elements K, U, and Th, which are responsible for the heat generated within the earth, are now highly depleted in the upper mantle because they are strongly partitioned into the crust when it forms. The lower mantle, however, still retains its original allotment of these elements. Consequently, it appears that the heat-producing elements have not been concentrated near the planet's surface as had been previously thought, but rather most (up to 75%) are still retained deep within the earth. It also provides a picture of the convecting upper mantle being heated from below. This arrangement affects both the modeling of convection in the mantle and the degree to which radiogenic heat production in the earth can be the driving force for convection and its surface manifestation–plate tectonics. The model also suggests that midocean ridge basalts are biased indicators of mantle properties, since they directly sample that relatively small portion of the mantle that has been most modified during the course of earth history.

An obvious test of such a model is whether it can explain other observations. Because Sr isotope ratios in basalts correlate well with ε_{Nd} values (Figure 9), the Sr data can clearly be considered consistent with the model. A more interesting test comes from a comparison with $^3He/^4He$ ratios in volcanic gases. The isotope ^3He is not produced in the earth in significant amounts, and therefore any that is presently coming out of the earth must date from the time of the earth's origin. Anomalously high $^3He/^4He$ ratios have been found associated with midocean ridges, oceanic islands, and some continental volcanic areas, like Yellowstone [*Craig et al.*, 1978]. This implies that the earth has not been already thoroughly outgassed. The model of a lower mantle that has been more or less isolated from the earth's surface for all or most of its existence is clearly consistent with the retention of gases deep in the earth. Furthermore, those basalts that appear to have the greatest contribution coming from the lower mantle on the basis of ε_{Nd} values also are associated with the highest $^3He/^4He$ ratios. This correlation needs further documentation but is in the correct sense. A possible problem area with the model involves Pb isotopes, where the model appears to be too simple to explain the data. This may be due to the likely situation that Pb isotopes in the mantle are strongly affected by the recycling of relatively small amounts of crust back into the upper mantle. Also Pb isotopes could be affected by any exchange of material between the core and the mantle [*Dupré and Allegre*, 1980]. Other problems with the model include the nature of the separation between upper mantle and lower mantle, especially since some 'leakage' from one into the other is necessary to satisfy the observations. Also, the mixing origin of the ε_{Nd} values intermediate between 0 and +10 could be questioned. A priori, one might not expect clustering of intermediate values if they are mixtures of two end-member compositions. Although there are problems, it is nevertheless surprising that a reasonably simple model can explain so many of the observations.

The Earth vs. the Moon

The Sm-Nd isotope system has also allowed comparison of the early histories of the earth and the moon in a way that was never before possible. When the initial ε_{Nd} values of lunar basalts are plotted in the same way shown in Figure 4, they show a large degree of scatter about the Chur curve (Figure 8). This scatter is much greater than that shown by terrestrial samples of equivalent age. Taking the lunar basalts to be representative of the ε_{Nd} values in the lunar mantle, it is clear that the moon became a highly heterogeneous body very soon after it formed. In contrast, the earth was apparently quite homogeneous throughout the first 1 to 1.5 eons of its existence. The current interpretation of this rather drastic difference is that it is related to the size of the bodies. The moon, which has only one sixth the mass of the earth, was heated sufficiently by the release of gravitational energy for melting to take place soon after accretion. This melting resulted in the formation of the lunar crust, which has a low Sm/Nd like the terrestrial crust, and complementary mantle layers with high (but variable) Sm/Nd [cf. *Taylor*, 1975]. The earth also probably became hot enough to melt very early. The moon, however, cooled relatively quickly after the initial burst of heat, and the layered structure became permanently 'frozen in.' By virtue of its greater size, much more initial energy was released in the earth, and still more may have been released when the earth's dense iron core formed. This energy was apparently sufficient to keep the earth a well-stirred cauldron for a billion years or more. It will be of considerable interest to determine if this theory of the size dependence of planetary history holds for Mars, Venus, and Mercury. The abundance of water may also be important, as the moon is devoid of water, in contrast to the earth.

Some Petrologic Inferences

One of the most interesting findings that has come from the Sm-Nd studies is that the ε_{Nd} values of young oceanic basalts correlate very well with the initial $^{87}Sr/^{86}Sr$ ratios (Figure 9). Although this correlation is not well understood yet, it is clearly a fundamental datum for all future models of earth evolution. Broadly speaking, it indicates that shifts in Sm/Nd in the earth's mantle are uniformly associated with complementary shifts in Rb/Sr. This simple observation has, in fact, paved the way for earth models of the type discussed above because it demonstrates a consistency and coherence between the behavior of elements that differ substantially in their geochemical properties. Its importance can be appreciated if one considers that prior to the Sm-Nd measurements, the existing data, from Rb-Sr and U-Th-Pb measurements, showed no relationship whatsoever, which made attempts to create any unified models extremely difficult.

Of more direct petrologic importance is the striking divergence of island arc ε_{Nd} values from the general trend defined by all other oceanic lavas. The shift toward higher $^{87}Sr/^{86}Sr$ is due to the influence of ocean water in the formation of these rocks. Ocean water contains substantial

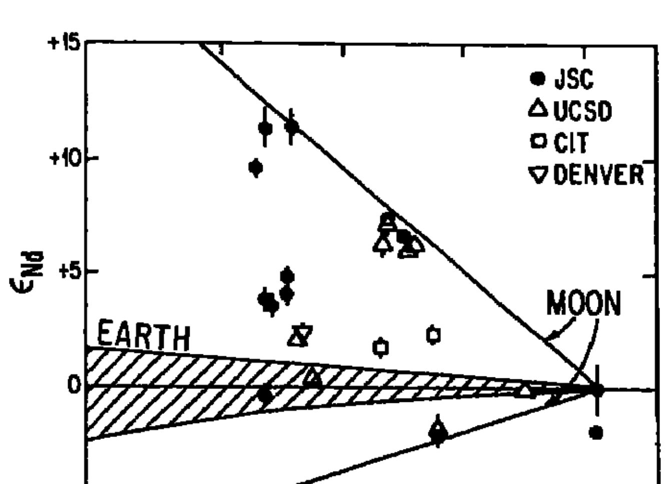

Fig. 8. ε_{Nd} values for lunar basalts (compare Figure 4). The large scatter indicates that the lunar mantle became highly chemically heterogeneous within the first few hundred million years after the moon formed. The earth's mantle, in contrast, was highly homogeneous for almost half of the earth's history. (Data from a summary by *Nyquist et al.* [1979]).

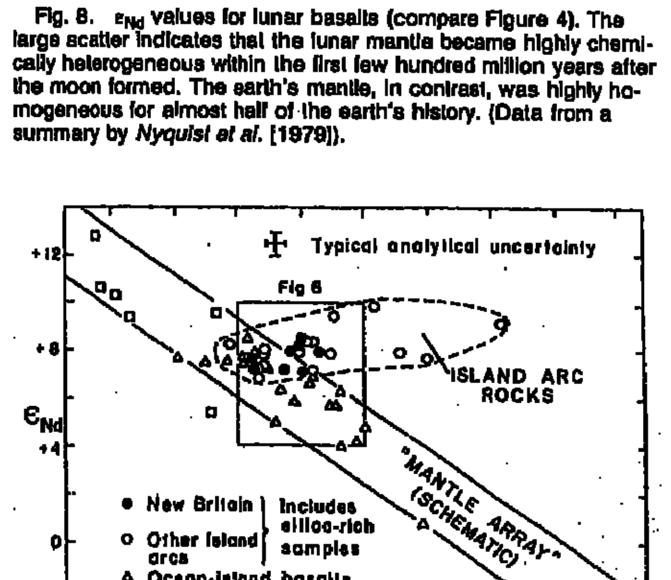

Fig. 9. Correlation of ε_{Nd} and $^{87}Sr/^{86}Sr$ (expressed here as ε_{Sr}) for most oceanic basalts is shown as the zone labeled 'Mantle Array.' Island arc volcanic rocks deviate markedly from this trend [*DePaolo and Johnson*, 1979].

amounts of Sr with high $^{87}Sr/^{86}Sr$, but since it contains vanishingly small amounts of Nd, there is no effect on ϵ_{Nd}. The only known material that has elevated $^{87}Sr/^{86}Sr$ in relation to ϵ_{Nd} is ocean floor basalt that has exchanged Sr with the heated ocean water which circulates through fractures in the solidified basalt at midocean ridges, driven by the heat of shallow magma bodies. The divergence of island arc ϵ_{Nd} values from the main trend has, therefore, been interpreted as evidence that the magmas that have erupted from island arc volcanos have been generated from the melting of ocean floor basalt that is descending into the mantle along subduction zones beneath the volcanos. This model for the origin of island arc magmas had been proposed much earlier, but these data represent one of the few good tests of the hypothesis. The insensitivity of Nd isotopes to hydrothermal alteration also make them useful for studying the isotopic composition of older parts of the ocean floor where unaltered basalt has been difficult to find.

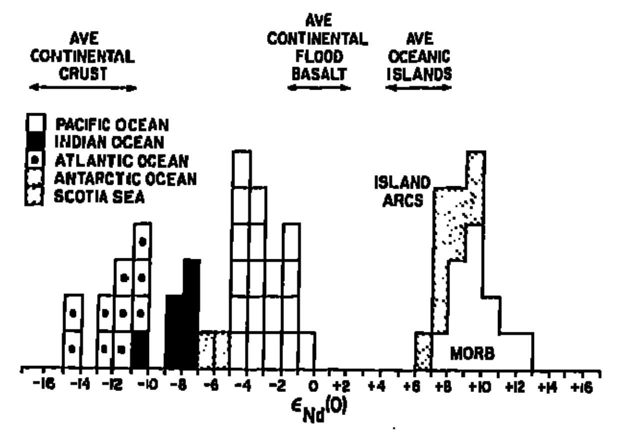

Fig. 11. ϵ_{Nd} values measured in ocean water and ferromanganese nodules from different oceans [from *Piepgras et al*, 1979]

Geochronology—Sensu Stricto

An additional feature of the Sm-Nd isotope system is that it can be used to determine the age of certain types of rocks that have been difficult to date by other methods. Furthermore, the Sm-Nd ages are resistant to mild metamorphism, which can obscure the true ages of rocks by disturbing the systematic isotopic relationships that yield the age information.

A rock type that has been particularly problematical is basalt and its coarser-grained equivalent, gabbro, especially those of great age. As noted above, these rocks are important because they are samples of the mantle isotopic ratios. Also, they are often valuable for paleomagnetic studies. An example of an age determination on an ancient gabbro where Sm-Nd is used is shown in Figure 10. In this case a precise Sm-Nd isochron age was obtained, whereas only crude ages could be obtained by Rb-Sr. Similar results were obtained by *Hamilton et al.* [1977], who dated a number of Archean volcanic terranes by Sm-Nd. The high precision of the determined age demonstrates that it is possible to obtain age resolution in very old rocks that is comparable to the resolution obtained for Phanerozoic rocks. Detailed knowledge of age relationships between different rock units, which will be necessary in order to compare the time scales and sequences of geologic processes at present with those of 2 to 3 eons ago, is therefore accessible by combining the Sm-Nd method with other methods that may be more sensitive for other rock types. Application of these precise dating techniques in consort with geologic studies of Precambrian terranes has yet to be undertaken. The Sm-Nd system also offers a means of better determining the synchroneity of volcanic units used in paleomagnetism for pole positions.

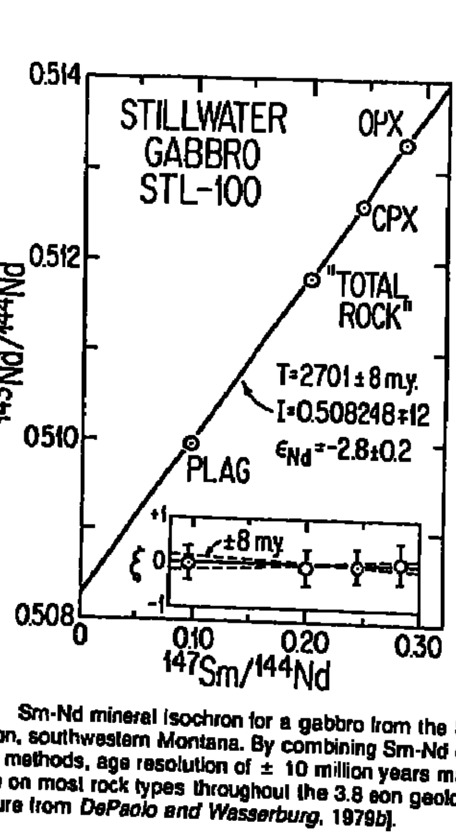

Fig. 10. Sm-Nd mineral isochron for a gabbro from the Stillwater intrusion, southwestern Montana. By combining Sm-Nd dating with other methods, age resolution of ± 10 million years may be obtainable on most rock types throughout the 3.8 eon geologic record. [Figure from *DePaolo and Wasserburg*, 1979b].

Oceanographic Applications

An interesting application of Nd isotopic studies has recently been reported by *Piepgras et al.* [1979]. They measured ϵ_{Nd} values in ocean water and ferromanganese nodules from different oceans. The results, seen in Figure 11, show that each ocean has a different but characteristic range of ϵ_{Nd}. The values measured do not represent detrital material but, rather, correspond to the values of Nd dissolved in the oceans. The values for the different oceans represent differences in isotopic composition of the Nd being carried into the oceans from the continents by rivers, coupled with a short residence time for Nd in seawater. The variability of the ϵ_{Nd} in water coming from continents is due to differences in the ages of the continental rocks (see Figure 5). For example, the regions that drain into the Atlantic are underlain by very old rocks, which consequently have large negative values of ϵ_{Nd}. On the other hand, the Pacific is ringed by young regions of the continental crust that have less negative ϵ_{Nd} values. These differences are preserved because the Nd entering the oceans precipitates out onto the seafloor too quickly to allow interocean circulation to homogenize the isotopic composition between oceans. The gross difference in ϵ_{Nd} values between the ocean masses and oceanic rocks clearly suggests that the bulk of the dissolved rare earths in the oceans is derived from continents. These preliminary studies show that Nd isotopic studies of oceans may be useful for the study of interocean mixing rates and the currents responsible for such mixing. The data also reveal a curious irony: the ϵ_{Nd} of different oceans are drastically different, while ϵ_{Nd} in the mantle beneath the oceans is virtually identical for all oceans! Apparently, for Nd isotopes the mantle is a more well-mixed system than the oceans.

Heterodoxy

Sm-Nd isotope studies are now firmly entrenched as a tool of first-magnitude importance for the unraveling of planetary histories. They will no doubt play a leading role in the characterization of evolutionary time scales for Mars, Venus, and Mercury if (or when) rock samples from those planets are returned to earth. But in conclusion, it may be prudent to raise an issue that has been glossed over in this presentation but still remains an important problem.

Having cited the correspondence between the Sm/Nd ratio of the earth and that of chondrites as a central strength of the Sm-Nd isotopic investigations, it is an edifying exercise to entertain the possibility that the Sm/Nd ratio of the earth is in fact different from that of chondrites by a small but significant amount. This issue has recently been called to attention by a revision of the Chur evolution curve that resulted from a set of precise measurements of meteorites by *Jacobsen and Wasserburg* [1980] at Caltech. Possible reasons for such a heretical circumstance include the fact that (a) small but significant Sm/Nd fractionation occurred during condensation or (b) chondrites do not precisely correspond to the composition of the earth for rare-earth elements. Theoretical calculations suggest that the former alternative is possible but not likely [*Boynton*, 1975]. The latter alternative is a fundamental geochemical question. If it could be proved true, the ramifications would be far-reaching, but at present there is no substantial indication that it is. Furthermore, the correspondence between the solar and chondritic Sm/Nd, and the present understanding of rare-earth behavior during condensation, suggest that it is an unlikely circumstance. A third possibility, somewhat more difficult to discount, is that a shift of the earth's Sm/Nd occurred as a consequence of formation of the moon by fission from the earth (Figure 12). Fission (or alternative but analogous processes) has been discussed more or less seriously for a long time [cf. *Ringwood*, 1975]. If such a process did occur, it is possible that the moon took with it more or less Sm or Nd than the chondritic proportions, leaving the earth with a perceptibly shifted Sm/Nd in relation to the chondrite average. It has in fact been suggested by Lawrence Nyquist and coworkers at the Johnson Space Center that the Sm/Nd of the moon is lower than chondritic [*Nyquist et al.*, 1977]. If the earth's Sm/Nd were higher than chondritic by 5%–7%, it would, among other things, remove the necessity of a layered mantle as diagrammed in Figure 7. However, it would make the ϵ_{Nd} = 0 clustering of the continental flood basalts even more puzzling. These and other implications of a fission origin for the moon will have to be reckoned with in future Sm-Nd studies, although the burden of proof must fall to proponents of this theory, for the foreseeable future. To return to the original assertion, it should be noted that no substantial evidence presently exists to suggest that the earth's Sm/Nd is anything other than precisely that of the average chondrite.

The next decade will most probably see the Sm-Nd data base increase enormously as more laboratories begin to make measurements. With these data and an enhanced information exchange with earth scientists of other disciplines, there is reason to expect that the understanding of earth evolution will mature considerably. A word of caution is also in order, however, as Nd isotopic measurements require a precision and accuracy that is at the limits of the capabilities of the best current instrumentation. It is, in fact, this necessity that prevented implementation of the method until the 1970's, when a new generation of mass spectrometers emerged [*Wasserburg et al.*, 1969]. A proper combination of precise measurements and careful consideration of the data will be necessary. Thus far, too few labs have sufficiently demonstrated the accuracy of their determinations of $^{143}Nd/^{144}Nd$ and Sm/Nd ratios. This fact, and the lack of interlaboratory comparisons via well-characterized standards, can leave even an expert at a loss when attempting to evaluate and compare data.

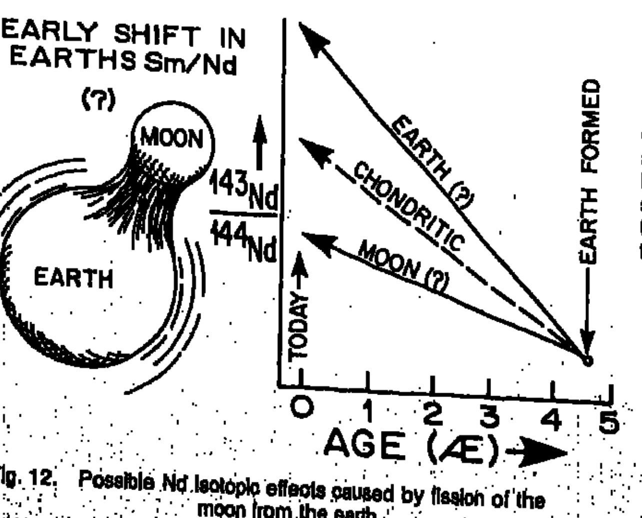

Fig. 12. Possible Nd isotopic effects caused by fission of the moon from the earth.

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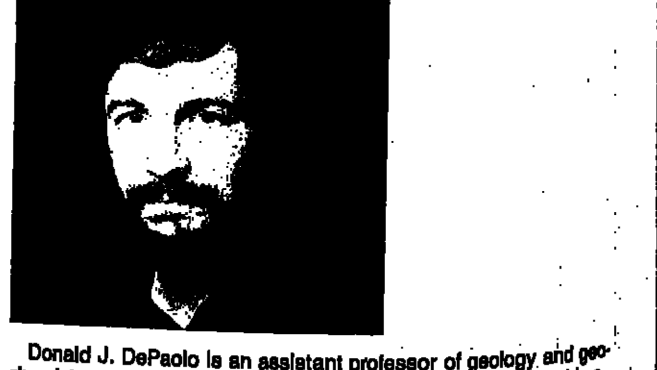

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News

Winter Snow Drought

The winter of 1980–81 can be best described as a 'snow drought.' Donald R. Wiesnet and Michael Matson of NOAA's National Earth Satellite Service, who have been monitoring snow cover by using satellite measurements, report that the December–February snow cover in North America averaged only 13.9 million square kilometers, which is four standard deviations below the 10-year mean (15.5 million km²). January 1981 snow cover (14.1 million km²) was the all-time lowest January since the satellite records began (1966). February, with only 14.2 million km², was the lowest February of record. As a result, Wiesnet and Matson are estimating that the December–March total will also be the lowest of record.

Figures for Eurasia are also below average, but not as dramatically as those of North America. When added together, snow cover on both continental land masses is the lowest (40.6 million km²) it has been since 1970.

Many regions are dependent on snowmelt to sustain their water supplies throughout the year. Although the drought in the northeastern U.S. has abated in recent weeks because of rainfall, other areas dependent on snowmelt runoff will be forced to plan for a reduced seasonal supply.

This item was submitted by Don Wiesnet, who is a member of AGU's Snow and Ice Commission.

Ocean Objectives for the '80's

Seven goals and objectives for services to ocean operations in the coming decade are outlined in a recent report by a task group of the National Advisory Committee on Oceans and Atmospheres (NACOA). The group also identified the principal driving forces expected to influence ocean use.

NACOA (*Eos*, February 24, p. 76) advises the President on ocean and atmospheric affairs. The Task Group on Services to Ocean Operations, chaired by Robert M. White at the University Corporation for Atmospheric Research, is one of six task forces established by NACOA to identify goals for ocean activities. The task group's recent report focuses solely on civilian programs.

The 'principal engines of change' singled out in the report are projected new ocean uses, shifting population growth to coasts, energy, fisheries, and science and technology. Among these are ocean thermal energy conversion (OTEC) and noxious waste disposal. These uses raise the need for assessment of possible environmental effects, the task group said. The big pushes for ocean use from science and technology, according to the report, come from satellite platforms, remote sensing, computer data banks, improved seabed geology studies, and ocean current studies. Also included in this category are advances in the National Climate Program, with implications for transportation, agriculture, and recreation.

In light of these driving forces, the task group outlined seven goals and objectives:

- *Ocean observation and prediction:* To implement a new ocean observation system by deploying advanced technology and by using the new information to predict in real time the state of the oceanic environment.
- *Navigation and positioning:* To realize an all-weather worldwide navigation system of high precision for resource exploration and development and for vessel traffic control.
- *Mapping and charting:* To improve the productivity, coverage, and responsiveness of present ocean mapping and charting programs.
- *Ocean data and information dissemination:* To establish a fast-response, technologically advanced, ocean environmental data archival and dissemination system to meet user needs.
- *Monitoring the ocean:* To design and implement a system for monitoring and assessing oceanic water quality and other parameters that affect ocean life and that are required for fishery and pollution management.
- *National ocean measurement capability:* To establish new measurement capabilities, including the development of submersible manned and unmanned vessels.
- *Improved Arctic and Antarctic Ocean information:* To ensure the provision of ocean and atmospheric information sources necessary for support in the polar regions.

Some of the task group's recommendations are not possible in President Reagan's proposed fiscal 1982 budget, however. For example, the first goal calls for development of a national ocean satellite program. Reagan cut the National Oceanic Satellite System (NOSS) from the budget (*Eos*, March 24, p. 123). In addition, the goal of ocean data and information dissemination requires the establishment of information systems to tie into coastal zone management and sea grant programs; both of these programs have been eliminated from NOAA's budget.

But the task group asserted that it takes a long-term view of needs and recognizes that 'short-term fiscal constraints may require adjustments in the recommended program planning.'

Members of the task group are chairman White; D. James Baker, Jr., University of Washington; Werner A. Baum, Florida State University; William A. Radlinski, American Congress on Surveying and Mapping; Owen W. Siler, Mantech International Corp.; Athelstan F. Spilhaus, University of Southern California; Sharron L. Stewart, Texas Deep Water Port Authority; Verner E. Suomi, University of Wisconsin; T. K. Treadwell, Texas A&M University; Don Walsh, University of Southern California; Warren M. Washington, National Center for Atmospheric Research; Elmer P. Wheaton, ocean technology consultant.—*BTR*

Lightning Superbolts

A rare type of lightning bolt previously not thought to occur in flatlands has been identified in Oklahoma prairie storms and could pose a danger to structures not built to withstand it. Researchers at NOAA say the discovery could indicate that buildings or power plants designed on the assumption that such destructive bolts do not occur in flatland might not be safe. The positive charge cloud-to-ground flashes once were thought to strike only when triggered by a tall structure or mountaintop, or, on rare occasions, at the end of a storm.

'Most storms never produce this kind of lightning. In a few storms, there may be one positive bolt, just as the storm is dissipating—sort of the last gasp of the storm,' according to David Rust of the National Severe Storms Laboratory. Rust added that the triggered bolts often are very high current, making them especially destructive. 'We know these bolts don't occur in garden variety storms. We are trying to find if the occurrence of this kind of lightning is linked with storm severity,' Rust said.—*PMB*

Decline in Tornado Death Rate Faces Test

Although records show a 3-year decline in tornado-related deaths, the trend could reverse between now and May, the peak tornado month. Therefore, NOAA and the Federal Emergency Management Administration (FEMA) are urging that the public be prepared to take the appropriate safety measures. 'It is vital that people not relax their vigilance against these destructive storms,' Richard E. Hallgren, director of the National Weather Service (NWS) said. 'If they do, we could witness an unwarranted number of casualties.'

Last year's 28 tornado-related deaths were the second lowest since records have been kept. There were 53 fatalities in 1978 and 84 in 1979. The 30-year average is 111. 'The low tornado death rate last year can be attributed, in part, to the occurrence of only five major killer tornados, compared to about 20 for an average year,' said Fred Ostby of NOAA.

'Other contributing factors include the tornado watch and warning programs, local spotter groups, and the tornado preparedness activities of the Federal Emergency Management Administration,' he added.

The most deadly 1980 tornados occurred at Grand Island, Neb., on June 3, when seven struck, killing five people and causing an estimated $300 million in damage. Major storms also hit in Kansas, Iowa, Indiana, and Pennsylvania last year. Kansas, Missouri, and Oklahoma had fewer than normal because of drought and excessive heat.

Statistics on numbers of tornados and the resultant deaths can be traced back to 1916. Since that date and through the 1980 tornado season, there were 25,968 tornados throughout the United States, resulting in 11,301 deaths. The increasing numbers of tornados, listed by decade in the table, are not due to more occurrences but reflect better reporting procedures.—*PMB*

Decade	Tornados	Deaths	Total Property Losses
1916–1919	356	1,043	6.7*
1920–1929	1,325	1,169†	6.8
1930's	1,685	1,945	6.6
1940's	1,554	1,786	6.9
1950's	4,793	1,409	7.2
1960's	6,816	934	7.5
1970's	8,575	987	8.5
1980 year total	864	28	—
Annual Averages			
1916–1980	406	177	—
1960–1980 (20 year)	813	97	—
1950–1980 (30 year)	702	112	—

*Storm damage by category: 5—$40,000 to $500,000; 6—$500,000 to $5 million; 7—$5 million to $50 million; 8—$50 million to $500 million; 9—$500 million and over.

†Includes most deadly tornado on record: March 18, 1925. This tornado killed 689 people, while sweeping a 220-mile path through southern Missouri, Illinois, and Indiana.

Gamma Ray Observatory Survives

Right now the budgetary position of NASA science projects for fiscal year 1982 is shaky, outside of the Space Shuttle Program. Two scientifically crucial missions being planned are the Gamma Ray Observatory (GRO) and the Venus Orbiting Imaging Radar (VOIR). President Reagan's proposed budgetary cuts have left both programs intact but delayed. For FY 1982, GRO will be able to continue at only 15% level—'about enough money to keep the papers shuffling,' according to a NASA official (*Science News*, Mar. 14, 1981). Nonetheless, the importance of planning the GRO mission, now scheduled for a launch date in 1988, has prompted the selection of instruments as follows:

Transient event monitor—which will detect the short, intense bursts of gamma rays of currently unknown origin and localize them with sufficient accuracy to determine their distribution in the galaxy.

High-energy gamma ray telescope—which will measure the energy spectrum and arrival directions of the highest-energy gamma rays that can be observed.

Imaging Compton telescope—which will provide gamma ray maps of the celestial sphere at medium energies.

Low-energy gamma ray spectrometer—which will search the lowest-energy gamma rays for spectral features, such as evidence of nucleosynthesis in supernovae.

Studies of gamma ray sources and gamma ray production are at the very heart of understanding the dynamics and evolution of stars, galaxies, and the universe. Gamma rays are produced in the most powerful processes in the universe, and their high energies qualify them as the most direct probe we have of these processes. The gamma rays measured by the GRO begin at about 100,000-eV (100-keV) energy and continue up to several hundred million electron volts energy (100 MeV, or more).

Principal investigators for the four instruments are Gerald J. Fishman, Marshall Space Flight Center, Huntsville, Ala., for the transient event monitor; James D. Kurfess, Naval Research Laboratory, Washington, D.C., for the low-energy detector; Carl Fichtel, Goddard Space Flight Center, Greenbelt, Md., Robert Hofstadter, Stanford University, and Klaus Pinkau, Max-Planck-Institute, Munich, for the high-energy telescope; V. Schoenfelder, Max-Planck Institute, Munich, John A. Lockwood, University of New Hampshire, B. N. Swanenburg, University of Leiden, the Netherlands, and B. G. Taylor, Space Science Department of European Space Agency, The Netherlands, for the medium-energy Compton telescope.

The predecessor spacecraft to the Gamma Ray Observatory are the High-Energy Astronomy Observatory 3, which looked at high-energy x rays and low-energy gamma rays, and the Small Astronomy Satellite 2 and the COS-B (a European satellite), which looked at high-energy gamma rays.

The Gamma Ray Observatory will be placed into a 400 km high, 28.5° inclined circular orbit. It is expected to provide information on gamma rays for 2 years. It will be one of the largest observatory satellites ever placed in orbit, weighing about 10,432 kg and measuring 7.6 m long and 3.8 m in diameter.—*PMB*

Columbia's First Shakedown Flight

The space shuttle orbiter *Columbia*, first of the planned fleet of spacecraft in the nation's space transportation system, will liftoff on its first orbital shakedown flight on or about the 10th of April 1981. Launch will be from the NASA Kennedy Space Center Launch Complex 39A, no earlier than 45 minutes after sunrise. Crew for the first orbital flight will be John W. Young, commander, veteran of two Gemini and two Apollo space flights, and U.S. Navy Capt. Robert L. Crippen, pilot. Crippen has not flown in space.

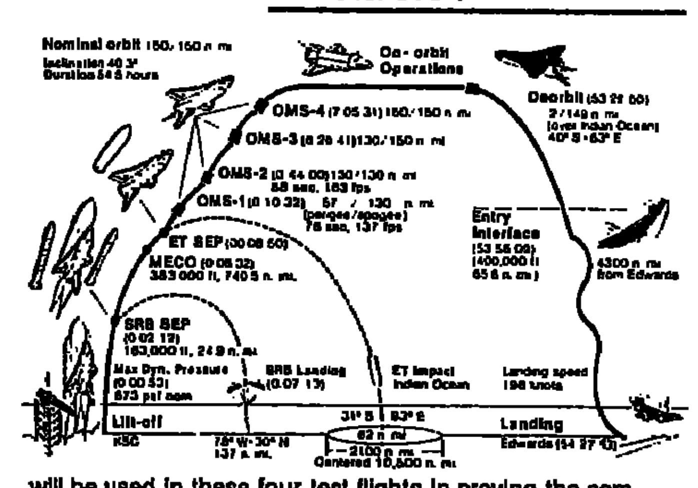
Columbia will have no payloads in the payload bay on this first orbital flight, but it will carry instrumentation for measuring orbiter systems performance in space and during its glide through the atmosphere to a landing after 54½ hours.

Extensive testing of orbiter systems, including the space radiators and other heat rejection systems, fills most of the STS-1 mission timeline. The clamshell-like doors on *Columbia*'s 4.6 by 18-m payload bay will be opened and closed twice during the flight for testing door actuators and latch mechanisms in the space environment.

Other tests will measure performance of maneuvering and attitude thrusters, the *Columbia*'s computer array and avionics 'black boxes,' and, during entry, silica-tile heat shield temperatures.

The first of four engineering test flights, STS-1 (see figure) will be launched into a 40.3° inclination orbit circularized first at 241 km and later boosted to 278 km. *Columbia*

NASA Space Shuttle Nominal Mission Profile for STS-1



will be used in these four test flights in proving the combined booster and orbiter combination before the Space Transportation System becomes operational with STS-5, now forecast for launch in September 1982.

After 'tower clear' the launch team in the Kennedy Space Center firing room will hand over STS-1 control to flight controllers in the Mission Control Center, Houston, for the remainder of the flight.

Columbia's two orbital maneuvering system hypergolic engines will fire at approximately 53½ hours over the Indian Ocean to bring the spacecraft to a landing on Rogers Dry Lake at Edwards Air Force Base, Calif., an hour later. The approach to landing will cross the California coast near Big Sur at 42,670-m altitude, pass over Bakersfield and Mojave, and end with a sweeping 225° left turn onto final approach.

Young and Crippen will land *Columbia* manually on this first test flight. A microwave landing system on the ground will be the primary landing aid in subsequent flights, with optional manual takeover. Kennedy landing teams will remove the flight crew and 'safe' the orbiter after landing.

The first three test flights land on Rogers Dry Lake, the fourth on the main runway at Edwards Air Force Base, and STS-5 will land on the 4570-m concrete shuttle landing facility runway at Kennedy Space Center.

STS-1 will be the first manned flight using solid rocket boosters. Note that no previous U.S. space vehicle has been manned on its maiden flight. [Material from NASA]—*PMB*

(News cont. on page 142)

(News cont. from page 141)

Volcanic Violence Varies Vista

This recent photograph shows Mount St. Helens' crater about a year after the volcano came to life on March 27, 1980, following 123 years of quiet. The lava dome (the darkened, raised area in the photo's center) developed during the volcano's eruptions over the last several months. The dome now measures 150 m in height and is 610 m long. The upper part of the photo shows the steep walls of the 2-km by 3.2-km crater. Currently, the crater occupies the general area of the north face of the mountain, which bulged for months prior to the violent May 18 eruption. (Photo courtesy of the U.S. Geological Survey, Department of the Interior)

Geophysicists

James Andrews, marine geologist and geophysicist, has assumed the position of director of the Ocean Science and Technology Laboratory of the Naval Ocean Research and Development Activity (NORDA).

Geophysical Events

This item comprises selected reprints from the *SEAN Bulletin, 6* (2), dated Feb. 28, 1981 (with data included through Mar. 10). *SEAN Bulletin* is a publication of the Smithsonian Institution.

Volcanic Activity

Mount St. Helens Volcano, Cascade Range, southern Washington, USA (46.20°N, 122.18°W). All times are local (GMT − 8 h). Mount St. Helens remained quiet as of March 10, as it has since the end of the lava extrusion episode of February 5–7. The February lava approximately doubled the volume of the composite dome in the crater, adding about 5×10^6 m^3 of new material to the 1.5×10^6 m^3 extruded October 18–19 and the 3.5×10^6 m^3 extruded December 27–January 4. All of the preexisting dome, except for a portion of the December-January southeast lobe, was covered by the February lava. Between February 8 and 21, the February lobe spread 12 m while sagging 3 m, resulting in dimensions for the new lava of 281 m in E-W direction and 119 m in maximum height above the crater floor.

Low-frequency volcanic earthquakes associated with the February lava extrusion ended February 9. Occasional bursts of seismicity continued to be recorded. One such burst, on February 10 at 0915, coincided with the emission of a cloud of steam, containing a minor amount of ash, that rose to 4-km altitude. Field crews reported hearing a boom prior to this event. Some rock avalanche events were also recorded after dome emplacement ended. A magnitude 5.5 tectonic earthquake occurred late February 13 (early February 14) GMT; see earthquake table, p. 144) about 12 km north of Mount St. Helens. As of February 28, about 175 aftershocks greater than magnitude 1 had been recorded. Through the end of February, seismographs continued to record a few rock avalanche events and bursts of seismicity of the type that has sometimes been associated with steam explosions. Clouds prevented observations of the crater for much of February, but clear weather on the 26th revealed evidence of numerous minor steam explosions on the north side of the lava dome.

Geodetic measurements showed a few centimeters of horizontal contraction of the Mount St. Helens edifice between February 4 and March 5. No significant movement of the northern crater rampart occurred after the early February dome emplacement, nor has there been any measurable deformation of the crater floor during this period.

The following, from W. G. Melson, is based on microprobe analyses performed on the 1980–1981 Mount St. Helens eruptives.

The SiO_2 content of essential ejecta from Mt. St. Helens underwent a slight increase in the 7 August eruption, which peaked in the 17–19 October eruption but remained lower than for the 18 May tephra. This temporarily reversed a prior trend toward more basic compositions, which resumed with the December–January and February dome enlargements. CaO, FeO, and MgO show an inverse relationship to SiO_2 (Figure 1), an expected relationship in a 'normal' fractionation sequence.

Information contacts: Don Swanson and Chris Newhall, U.S. Geological Survey Field Office, 301 E. McLaughlin, Vancouver, Washington 98663.

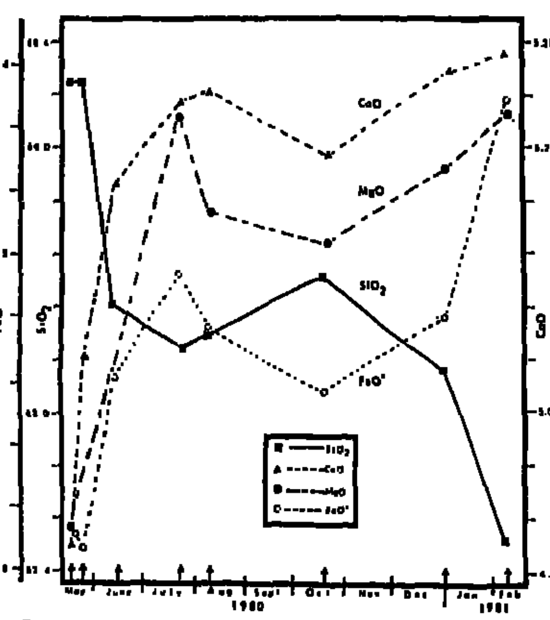


Fig. 1. Change of SiO_2, CaO, FeO, and MgO as a function of time of eruption. The analyses are by electron microprobe analyses of fused powders, performed at the Smithsonian Institution, Division of Petrology and Volcanology, by W. G. Melson, J. Nelen, and T. O'Hearn. Each analysis is the average of the following number of individual analyses of essential ejecta: May 18, 9; May 25, 11; June 12, 9; July 22, 7; Aug. 7, 10; Oct. 17–18, 11; Dec.–Jan. dome enlargement, 6, Feb. dome enlargement, 1 (sample from D. A. Swanson, U.S. Geological Survey). Analytical precision for each analysis is about a 2σ of: SiO_2 = 0.62, FeO' (all Fe as FeO) = 0.43, MgO = 0.33, CaO = 0.17.

Christina Boyko, Steven Malone, Elliot Endo, and Craig Weaver, Graduate Program in Geophysics, University of Washington, Seattle, Washington 98195.

Robert Tilling, U.S. Geological Survey, Stop 906, National Center, Reston, Virginia 22092.

W. G. Melson, Division of Petrology and Volcanology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (GMT + 4 h). A fissure eruption started February 3 on the north side of the updomed summit region that surrounds Bory and Dolomieu craters (see Figure 2). Lava extrusion from this area

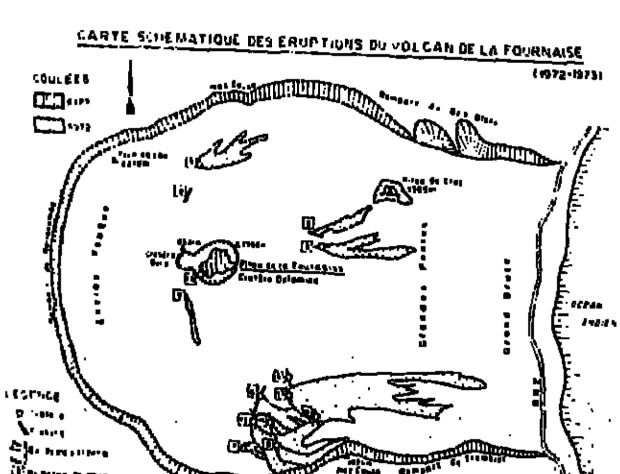


Fig. 2. Map of the caldera of Piton de la Fournaise (from Krafft, M., and Gerente, A., L'activité de Piton de la Fournaise entre Octobre 1972 et mai 1973, *C. R. Acad. Sci. Paris, Ser. D, 284*, 607–610, 1977).

continued until February 25. After about 13 hours of seismicity, fissures opened on the southwest side of the summit area and began to eject lava. The eruption was continuing as of March 3.

Activity north of the summit, February 6–25: During the first few days of the eruption, lava was extruded from a series of radial fissures in the northern summit region. By February 6, lava fountaining was confined to a spatter cone at 2350-m altitude at the lower end of a fissure that opened February 4. Lava flows emerged from one or two vents about 300-m downslope from the active spatter cone and moved about 1.3 km to the east (see Figure 2). Fountaining was most intense February 10 (30 m high) and February 18 (100 m high). About February 19, a small lava lake formed inside the active cone. Lava fountains rose a few meters above the lake surface. A 2-m-diameter vent high on the cone emitted blue and yellow flames 3–4 m high. The spatter cone partially collapsed February 20. Lava overflowing the collapsed area formed a front 100 m wide.

Fountaining and extrusion of lava flows began a rapid decline on February 23 and stopped on the 25th. Several million cubic meters of lava were extruded during the activity February 3–25.

Activity southwest of the summit, beginning February 26: Seismographs at Réunion's volcano observatory began to record a series of small (about magnitude 1) local earthquakes around midnight on the night of February 25–26. Earthquakes became increasingly frequent that morning and by 1230 were occurring once every 15 s under the summit's Bory Crater. Harmonic tremor started at 1300, and the beginning of eruptive activity was observed at 1306. Two minutes later, a large black cloud rose to 2 km height. Two en-echelon radial fissures, trending N74°E, opened on the southwest side of the updomed summit region. The upper fissure, 200–300 m long, extended from 2400-m to 2250-m altitude. The lower fissure, offset about 100 m from the base of the upper fissure, extended about 100 m farther downslope. Lava fountains rose to 15-m height from the entire length of the upper fissure, while fountains from the lower fissure were 50–60 m high. After half an hour, lava from the two fissures had merged into a single aa flow 2 km long that spread onto the caldera floor and moved toward the south caldera wall (Figure 2). Midafternoon outflow rates from the two fissures were about 300 m^3/s (about 1×10^6 m^3/h), much higher than at any time during the northern summit region activity earlier in the month. The lava was an aphyric basalt, as was the February 3–25 material. By about 1800, lava fountaining along the upper fissure was concentrated at its lower end, where a cone was growing. Seismicity ended within a few hours of the start of eruptive activity on February 26, a pattern similar to that observed at the beginning of the eruption February 3.

Lava fountaining along the entire lower fissure continued until 0200 on February 27, then was limited to the middle of this fissure, where a cone formed. The rate of lava outflow declined to 60 m^3/s by the morning of the 27th and 10 m^3/s the following day. Fountaining from the upper fissure stopped February 28 but continued from the lower fissure, building a 15-m-high spatter cone. Two other spatter cones formed along the lower fissure March 1, with activity concentrating at one of these, also about 15 m high, on March 2. The rate of lava production remained at about 10 m^3/s as of March 2, feeding a slow-moving lava flow that was incandescent for the upper 1.5 km of its length.

Information contacts: Maurice Krafft, Equipe Volcain, B.P. 5, 68700 Cernay, France.

L. Stieltjes, BRGM, Service Geologique Regional, B.P. 1206, 97484 Saint Denis, Réunion.

Volcano Observatory of Réunion, c/o Institut de Physique du Globe, Tour 14, Université de Paris VI, Place Jussieu, 75230 Paris Cedex 05, France.

Krafla Caldera, Mývatn Area, Iceland (65.71°N, 16.75°W). All times are GMT. The following is a report from Karl Grönvold and Páll Einarsson.

An eruption started in the Krafla fissure swarm shortly after 1400 on 30 January. The early and main parts of the eruption are described in last month's *Bulletin*.

The initial vigorous phase lasted from the first day until the early morning of 31 January. Then activity began to decrease, with shortening of the crater row, which initially extended 2 km and then decreasing activity in the craters and declining lava production.

The final activity in the craters died out just after 1400 on 4 February. During the eruption, slow deflation over the Krafla magma reservoirs, 8–9 km to the S, was observed, but inflation started again at about the same time as the eruption ceased. The lava covered 6.3 km^2 and appeared to be similar in volume to the two previous eruptions in July and October 1980.

Considerable movement of faults extending about 1 km N of the main lava (about 8 km N of the craters) was observed. Large volumes of steam emitted from these faults suggest that lava again forced its way down into the faults and then northward. Renewed earthquake activity in this region on 1 February was possibly associated with this fault movement.

By early March the inflation of the magma reservoirs had regained over half of the deflation that accompanied the eruption. Experience indicates that previous ground levels will be reached about the end of March to early April.

Information contacts: Karl Grönvöld, Nordic Volcanological Institute, University of Iceland, Reykjavik, Iceland.

Páll Einarsson, Science Institute, University of Iceland, Reykjavik, Iceland.

Etna Volcano, Sicily, Italy (37.73°N, 15.00°E). The Istituto Internazionale di Vulcanologia reports explosions and extrusion of lava from Etna's northeast crater. After a period of ash emission at the end of January and the beginning of February, stronger activity began with intense explosions the evening of February 5. Lava flowed through a breach in the west-to-northwest side of the northeast crater cone. It formed three lobes that moved west, northwest, and north and covered the upper northwest slope of the volcano. The northern lobe, the largest, traveled about 2 km to about 2600-m elevation, where it had a 1.2-km front. The eruptive activity stopped the evening of February 7.

Eruptions occurred at the northeast crater in 1975 and 1977–1978. Explosions and extrusion of lava were most recently observed there in September 1980.

Information contacts: Romolo Romano, Istituto Internazionale di Vulcanologia, Viale Regina Margherita, 6, 95123 Catania, Italy.

John Guest, University of London Observatory, Mill Hill Park, London NW7 2QS England.

Mt. Erebus Volcano, Ross Island, Antarctica (77.58°S, 167.17°E). The following is a report from Philip Kyle.

The summit crater of Mt. Erebus was visited by Japanese, New Zealand, and U.S. scientists during late December and early January. A 1-day visit was also made in November. The anorthoclase phonolite lava lake (first observed in 1972) was still present, although its level may have been slightly lower than that observed over the last 2 years. The 120-m-long oval-shaped lava lake still shows a simple convection pattern with lava apparently welling up from two centers about a third of the way from each end.

Small strombolian eruptions continued at a frequency of between two and six per day. The noise associated with the eruptions consisted of a long drawnout roar. This contrasted with the strong explosive eruptions heard in previous years. Although no eruptions were witnessed they are believed to occur from the small vent called the Active Vent, which is adjacent to the lava lake. Very few bombs were found on the main crater rim during December, but in January there were a few sharper explosive eruptions and these ejected material onto the rim.

The three nations mentioned above commenced a new project and installed three permanent seismometers on the mountain. The seismometers have radio-telemetry links with Scott Base (the New Zealand research station on Ross Island). Two seismometer stations are on the W flank of the volcano at altitudes of between 1500 and 1900 m about 5 km from the crater rim. It is anticipated that these stations will run until April, when darkness sets in. The stations should be reactivated in October, when new batteries will be installed and the solar panels will function. The third station is at the summit of Mt. Erebus, and has its batteries buried in warm ground. It is hoped that it will operate all year round. The summit station is also transmitting the output from an acoustic sensor (a microphone which monitors the sounds of volcanic eruptions) and a large wire loop around the crater, which monitors induced currents. A fourth permanent seismic station will be installed in December 1981.

Preliminary observations from the seismic network, which can detect events with magnitudes less than 1, indicate a surprisingly high level of microearthquake activity, with up to 10 events per day. Some of these are apparently tectonic earthquakes occurring some distance from Mt. Erebus. Antarctica has been considered aseismic, but this is apparently not the case, at least not for microearthquakes with magnitudes less than 3.

Information contact: Philip R. Kyle, Institute of Polar Studies, Ohio State University, Columbus, Ohio 43210.

Merapi Volcano, Java, Indonesia (7.54°S, 110.44°E). The lava dome that began to emerge at the summit of Merapi in 1979 was still growing in February and had reached an altitude of 2947 m. Lava fragments from the east and central part of the cone had moved 2.0 km toward the Batang River and 250–500 m farther in December. Personnel at the Ngepos Observatory have counted 34 larger and 468 smaller lava avalanches in recent months. [The time interval was not reported.] Nuées ardentes de avalanche occurred in November and December but were confined to the summit area of Merapi. Two Minakami A-type earthquakes, the first in several months, were recently recorded by the seismograph at the Babadan Observatory. No important lahars have occurred along the Putih, Bebeng, and Krasak rivers since the beginning of this year's rainy season.

Information contact: A. Sudradjat, Director, and I. Pardyanto, Senior Geologist, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Paluweh (Rokatenda) Volcano, Lesser Sunda Islands, Indonesia (8.32°S, 121.71°E). All times are local (GMT + 8 h). The Volcanological Survey of Indonesia provided further details about the intermittent explosive activity that began on November 5 and continued through the end of January. The 40-m-diameter crater mentioned in last month's *Bulletin* was formed during one of the early November eruptions and is situated on the north northeast upper part of the volcano. Bombs from the 1-km-high eruption column on November 9 measured up to 60 cm in diameter. Beginning January 18, renewed activity was reported. A hot air wave was felt by the inhabitants of two east flank villages. About 1850 persons were evacuated from the danger zone. After the explosions on January 31 a new lava dome was observed in the crater. Activity declined gradually, and the volcano appeared to be normal again on February 1 at 1200. No casualties from Paluweh's November–January activity were reported.

Information contact: Same as for Merapi.

Semeru Volcano, Java, Indonesia (8.11°S, 112.92°E). Ash emission continued at an average rate of once every 56 min in November and December. Ash columns typically rose 500–700 m above the crater rim. Some clouds were less ash-rich, as indicated by a grayish color. Incandescent lava fragments were sometimes visible at night. Strombolian-type eruptions have accompanied the formation of the lava dome since extrusion began in 1967.

Lava avalanches from the dome have usually been contained at about 3-km altitude on the south flank of the volcano in the upper reaches of the Kembar River, but one traveled farther down the river valley in early December. In advance of this year's monsoon rains the Volcanological Survey of Indonesia has alerted local authorities to the south and southeast of the danger of lahars along the Kembar, Kobokan, Rejali, Sat, and Glidik rivers.

Information contact: Same as for Merapi.

Pacaya Volcano, southern Guatemala (14.38°N, 90.60°W). Pacaya displayed weak strombolian activity during a visit by Michigan Technological University geologists on February 14. This is the first strombolian activity observed at Pacaya since 1975. Gas emissions have characterized the activity since late 1977.

Lava was fountaining to 200 m at 10-s to 1-min intervals from two coalesced spatter vents in the center of MacKenney Crater, high on the west northwest flank. Four subsidiary vents, two north of the spatter vents and two west of them (in the direction of the volcano summit), also ejected lava. New pahoehoe lava flows, some of which were moving, had filled the northern half of the crater floor to the rim. The fountaining was interspersed with intense, pulsating gas emission from the spatter vents.

By February 20, when Robert Hodder climbed Pacaya, one lava flow had traveled a quarter of the way (about 200 m) down the north flank of MacKenney Crater cone, over one of the September 1969 flows. Within the crater, cracks and pressure ridges in the lava crust indicated continued lava movement. Strombolian activity was occurring at about 30-min intervals. Patches of sublimate were visible on the southeast crater wall.

During a second climb on February 28, Hodder observed that aa lava had flowed about 750 m from the crater rim to the base of MacKenney Crater cone, into the trough between it and the rim of the older Pacaya edifice. The level of lava in the crater had risen. The two vents observed on February 14 had totally coalesced and had built cones about 15 m high. The lava crust seemed solid, but incandescence showed through surface cracks at night. Strombolian activity occurred about every 20 min. Large cow-dung bombs, hurled as high as 100 m, fell onto the cones and the lava crust. Bomb ejection was sometimes preceded by a puffy steam cloud at least 300 m high. Sublimate solidly coated the southeast crater wall. Hodder noted that this eruption seemed similar to that of 1969.

Information contacts: William I. Rose, Jr., T. J. Bornhorst, and Craig Chesner, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan 49931.

Robert Hodder, Department of Geology, University of Western Ontario, London N6A 5B7, Ontario, Canada.

Santiaguito Dome, western Guatemala (14.76°N, 91.55°W). All times are local (GMT − 6 h). Three geologists from Michigan Technological University spent February 12 on Santiaguito Dome, a dacite complex which has been growing on the southwest flank of Santa Maria Volcano since 1922. At 1410 an explosion at Caliente Vent (at the east end of the dome) sent up a 400-m-high vertical column of fine ash. It was the only explosion in 8 hours' observation, but two increases in the vent's vapor plume indicated additional gas emissions during that time. The vent was more active late last year when other geologists visited it.

Large dust clouds in the early morning suggested that avalanching was continuing down the southeast slope of the dome. Fine ash coating the leaves and the ground was notable in the area northwest of the volcano.

Information contact: William I. Rose, Jr., T. J. Bornhorst; and Craig Chesner, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, MI 49931.

Arenal Volcano, western Costa Rica (10.48°N, 84.72°W). The following information is from Jorge Barquero Hernández.

The vent located at 1450-m altitude at the western end of the elliptical summit crater area continued to emit block lava and vapor. The lava flow that began to descend the northwest flank in early July had reached 1100 m by November and continued to advance. Two other flows that had been active in July on the southwest and west flanks had stopped advancing by November. A newer flow, the 34th since nearly continuous extrusion of lava began in 1968, descended the west flank to 1300-m altitude, where it bifurcated into lobes moving west and northwest over the channels of older flows. The front of the west lobe was at 800-m altitude on November 11, and the other (NW) lobe had reached 1200-m altitude by November 12. A mean velocity of 1.5 km/h was measured on blocks in the central flow channel on the upper west flank.

The vapor emissions observed between August 15 and 20 were a little more voluminous than normal. They included small quantities of ash and were accompanied by rumblings. The constant noise from the violently escaping gases was occasionally loud enough to be heard in nearby villages. Vegetation on the upper part of the volcano's eastern flank had been burned by the effects of the vapor eruptions. The loss of vegetation had noticeably augmented fluvial erosion.

In a separate communication, Jorge Umaña reports that as of early February Arenal continued to emit lava and vapor from the summit area. The gases had a high chlorine content.

Information contacts: Jorge Barquero Hernández, Editor, Boletín de Vulcanología, Escuela de Ciencias Geográficas, Universidad Nacional, Heredia, Costa Rica.

Jorge Umaña, Instituto Costarricense de Electricidad, Depto. de Geología, Apartado #10032, San José, Costa Rica.

Poás Volcano, northwest of San José, Costa Rica (10.18°N, 84.22°W). All times are local (GMT − 6 h). Fumarolic activity continued at Poás during August and early September. Sulfurous vapors emitted under pressure from the north wall of the dome in the crater lake rose noisily in an almost continuous column about 200 m high. The lake color was turquoise green. Temperatures registered 40° C in the north part of the lake, 45° C in the south part near the dome, and 70–90° C in accessible fumaroles on the dome.

On September 11 at 0950 an explosion from the southern part of the lake (near the dome) produced a 250-m-high column of lakewater laden with ash, sand, and small blocks rich in mineralized sulfur. The ejecta fell back into the lake and onto the eastern shore, where they covered an area of 50 m^2. A landslide that originated from the northwest part of the dome, the area of the greatest fumarole activity, deposited debris in the lake and changed the morphology of the eastern sector of the crater.

The initial activity was followed by similar explosions throughout September and October. Scientists at the Institute had predicted resumption of phreatic activity from the thermal behavior of the lake, which had been similar to the pattern observed before previous such eruptions. Temperatures declined slightly in October, to 40° C in the northeast part of the lake from 45° C in September, and to 45° C in the southeast sector (near the September explosion site) from 60° C in September. Temperatures of the accessible fumaroles on the dome continued to oscillate between 70° and 90° C in September and October.

Information contact: Jorge Barquero Hernández, Editor, Boletín de Vulcanología, Escuela de Ciencias Geográficas, Universidad Nacional, Heredia, Costa Rica.

Kavachi Volcano, Solomon Islands, southeast Pacific (9.03°S, 157.93°E). All times are local (GMT + 11 h). Submarine activity at Kavachi has been observed since early October. On November 11 at 1215 a Solair flight diverged from its normal route to observe the volcano. Drs. Hughes and Dunkley of the Geological Division, Ministry of Natural Resources, report that a dense, nearly verti-

(News cont. from page 143)

cal steam jet billowed to approximately 300 m but dissipated as the plane approached. The eruption site was marked by white water, and a stream of muddy, turbid, pale-brown water extended several kilometers northeast from the volcano. On December 3, Dunkley observed an area of discolored water several hundred meters wide extending northwest (down current) about 4 km. No eruption was in progress.

Kavachi's last eruption in June-July 1978 produced a small, ephemeral island, its eighth island-forming eruption since 1950.

Information contact: Deni Tuni, Geological Division, Ministry of Natural Resources, Honiara, Solomon Islands.

Sakurazima Volcano, Kyushu, Japan (31.58°N, 130.65°E). After an active month in January, when 18 explosions from Sakurazima were recorded, only five explosions were detected in February (see table). The highest February ash cloud rose 1.2 km on the 21st. The February explosions caused no damage.

Explosions at Sakurazima, February 1981

Date	6	9	17	22	28	Total
Number of explosions:	1	1	1	1	1	5

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

Tarumai Volcano, Hokkaido, Japan (42.68°N, 141.38°E). In February, 1,121 seismic events were recorded at Tarumai (see Figure 3), the most in any month since 1967, when the Japan Meteorological Agency began routine measurements at the volcano. Seismicity has irregularly but gradually increased in the past 14 years (see Figure 4). Tarumai last erupted December 1978–May 1979, but no eruption has occurred during the current increase in seismicity.

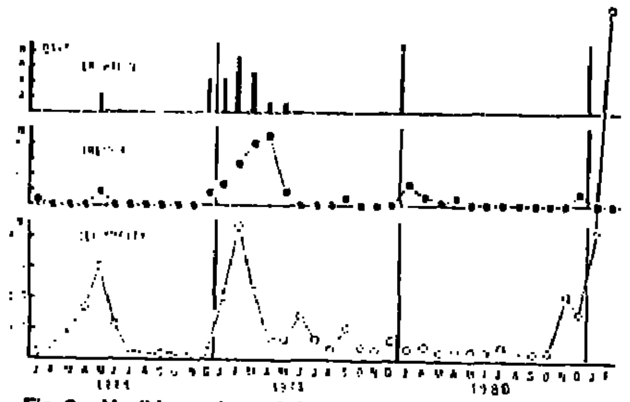


Fig 3. Monthly numbers of days in which occurred: eruptions (top); harmonic tremor events (center); and recorded earthquakes (bottom) at Tarumai, January 1978–February 1981.

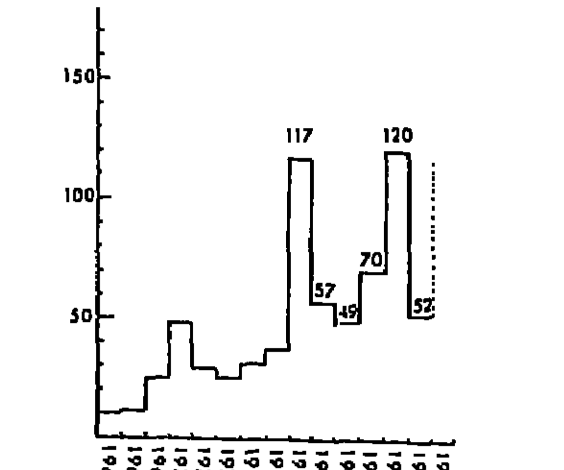


Fig. 4. Yearly means of monthly seismicity, 1967–1980.

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

Earthquakes

TABLE 1. Summary of Earthquake Occurrences

Date	Time, GMT	Magnitude	Latitude	Longitude	Depth of Focus	Region
Feb. 1	1320	5.4 m_b	36.45°N	1.66°E	10 km	Northern Algeria
Feb. 14	0609	5.5 M_L	46.351°N	122.238°E	7.3 km	12 km north of Mt. St. Helens
Feb. 14	1728	4.6 m_b	41.05°N	14.70°E	10 km	Southern Italy
Feb. 17	1519	6.8 M_s	21.60°S	169.35°E	shallow	Loyalty Islands region, South Pacific
Feb. 24	2054	6.7 M_s	38.21°N	23.02°E	shallow	Greece
Feb. 25	0236	6.4 M_s	38.16°N	23.15°E	shallow	Greece
Mar. 4	2158	6.5 M_s	38.31°N	23.43°E	shallow	Greece

The February 1 event caused the collapse of several buildings damaged by seismicity in the El Asnam area, where earthquakes on October 10 killed thousands and left about 400,000 homeless. Eight people died of heart attacks triggered by the Italy earthquake, which occurred near the epicenter of the devastating November 23 shock that killed several thousand persons. There were no reports of casualties or damage from the Loyalty Islands event. The Greek earthquakes killed 21 people and injured 400, while causing considerable damage in the Athens and Corinth areas. Numerous smaller shocks occurred between the three events listed above.

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225.

Steven Malone, Christina Boyko, Elliot Endo, and Craig Weaver, Graduate Program in Geophysics, University of Washington, Seattle, Washington 98195.

Fireballs

Austria, January 28, 225819 GMT. The following is a report from Zdeněk Ceplecha.

A fireball of −8 absolute magnitude was photographed by three Czech stations of the European network. The fireball traveled a 41-km luminous trajectory in 1.8 s. The following results are based on all available photographs from rather distant stations (210 to 290 km from the trajectory).

	Beginning	Maximum Light	Terminal
Velocity, km/s	28.4	27.4	6
Height, km	72.7	59.9	38.3
Latitude	47.234°N	47.30°N	47.424°N
Longitude	15.147°E	15.11°E	15.044°E
Magnitude	−3.5	−8.1	−3.5
Mass, kg	0.9	0.8	none
Z R	33.3°	—	33.5°

Fireball type: I
Meteorite fall very improbable.

Radiant, 1950.0	Observed	Geocentric	Heliocentric
Alpha	138.8°	138.5°	—
Delta	15.4°	14.1°	—
Lambda	—	—	82.8°
Beta	—	—	−1.3°
Initial Velocity, km/s	28.7	26.4	37.1

Orbit, 1950.0	
A	2.08 AU
E	0.793
Q	0.430 AU
Aphelion	3.7 AU
Omega	105.8°
Ascending node	128.618°
Inclination	1.8°

Meteor Shower: A bright member of Psi Leonids not excluded.

Information contact: Zdeněk Ceplecha, Ondřejov Observatory, 251 65 Ondřejov, Czechoslovakia.

Labrador Sea, December 31, 1980, 0132 GMT.
Observers: Capt. Schoune, F/O Van Themsche of Sabena Flight 568 (Chicago–Brussels).
Location: 55.62° N, 44.85° W, aircraft course 110° magnetic, altitude 11.1 km.
First sighting: 20° magnetic, 20° above the horizon.
Last sighting: 0° magnetic, at the horizon.
Duration: ½ s.
Brightness: As bright as the full moon.
Color: white.
Information contact: Same as for West Germany.

Gulf of Thailand, January 11, 1228 GMT.
Observers: Capt. De Montblanc, F/O Legrain, F/E Goossens of Sabena flight 272 (Kuala Lumpur–Bangkok).
Location: 8.2° N, 100.38° E, aircraft course 006° magnetic, altitude 10.5 km.
First sighting: 30° magnetic, 30° above the horizon.
Last sighting: 90° magnetic, at the horizon.
Duration: 5 s.
Brightness: As bright as the full moon.
The object had a round, white-blue head and a very long, straight, brilliant yellow tail.
Information contact: Same as for West Germany.

West Germany, January 30, 1717 GMT.
Observer: Capt. Luebbert of Lufthansa flight LH 948 (Hamburg–Stuttgart).
Location: 20 km south of Leine (just north of Kassel), aircraft course 190° magnetic, altitude 10 km.
First sighting: 170° magnetic, 40° above the horizon.
Last sighting: 195° magnetic, 8° above the horizon.
Duration: 2 s.
Apparent brightness: As bright as the full moon.
The circular white object moved very slowly. No disintegration was observed before it disappeared.
Information contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

Northern Italy, August 13, 1980, 0200 GMT.
Observers: Silvano Ghedini, Luigi Baldinelli, and Andrea Ferri.
Location: Bologna, Italy (44.5° N, 11.33° E).
First sighting: right ascension 2 h 30 min, declination +60°.
Last sighting: right ascension 18 h 00 min, declination +75°.
Magnitude: −15.
Color: green.
Train: persistent.
Information contact: Same as for southern Europe.

Austria, January 29, 182530 GMT. The following is a report from Zdeněk Ceplecha.

A very slow-moving fireball of −9 maximum absolute magnitude was photographed by two Czech stations of the European network. The fireball traveled a 54-km luminous trajectory in 5.1 s. The time of the fireball passage depends on three visual observations in Austria reported to us by Dr. G. Polnitzky. The following results are based on the two photographic records.

	Beginning	Maximum Light	Terminal
Velocity, km/s	11.56	11.10	6.88
Height, km	67.0	48.1	32.6
Latitude	48.333° N	48.38° N	48.4176° N
Longitude	14.446° E	14.74° E	14.9918° E
Magnitude	−2.3	−8.9	−2.7
Mass, kg	20	15	1.0
Z R	50.4°	—	50.8°

Time, s	Height, km	Velocity, km/s	Deceleration, km/s²	Dynamic Mass, kg	Photometric Mass, kg
0.0	63.79	11.536	−0.067	20.1	20.4
1.0	56.47	11.429	−0.162	18.9	19.0
2.0	49.28	11.168	−0.392	16.5	15.7
3.0	42.38	10.540	−0.946	13.5	8.8
4.0	36.10	9.021	−2.29	5.9	4.7
4.5	33.45	7.59	−3.55	1.9	1.7
4.684	32.61	6.88	−4.18	1.0	(1.0)

Assumed density of the meteoroid: 2.2 g/cm³
Dynamic and photometric masses are in excellent agreement. A meteorite fall of about 1-kg mass is quite certain.

Predicted impact area: 48.4278° N ± 0.0040, 15.1320° E ± 0.0105 (near Traunstein, Austria).

Fireball type: II
Predicted meteorite type: carbonaceous chondrite.
The activities in the search area will be organized by Gerhard Polnitzky, University Observatory, Vienna (see information contact, Labrador Bay Fireball for address).

Radiant, 1950.0	Observed	Geocentric	Heliocentric
Alpha	5.9°	346.7°	—
Delta	20.8°	0.3°	—
Lambda	—	—	33.48°
Beta	—	—	0.68°
Initial Velocity, km/s	11.61	4.01	32.90

Orbit, 1950.0	
A	1.234 AU
E	0.225
Q	0.9561 AU
Aphelion	1.512 AU
Omega	147.4°
Ascending Node	309.11°
Inclination	0.68°

Information contact: Same as above.

Southern Europe, November 11, 1980, 1736 GMT. Maurizio Eltri provided the following additional observations of this fireball from Italy, supplementing the report on pp. 12–13 of *SEAN Bulletin*, *5*(11).

Information contact: Maurizio Eltri, Sezione Meteore, Unione Astrofili Italiani, Via Marcantonio Bragadin No. 2, 30126 Lido, Venezia, Italy.

Observer	Location	Trajectory	Duration	Magnitude	Color	Size/Shape	Train
Bruno Penso	Lido, Italy (45.4° N, 12.4° E)	NNE to SSW	—	−10	Blue-White	—	Did not persist
Luigi Baldinelli	Bologna, Italy (44.5° N, 11.3° E)	From RA 1 h 50 min, decl. +47° to RA 19 h 45 min, decl. +3°	6–7 s	−15	—	Diameter of the moon	Persistent for 15 min, possible final flare
Ferrucio Castelli	Pegli, Italy (44.38° N, 8.82° E)	SSE to SW	—	—	Orange-green	35-min diameter, droplike form	—
Luciano Tesi	S. Marcello Pistoiese, Italy (44.05° N, 10.78° E)	NE sky to SW horizon, passed 3° east of zeta Cygnus	—	−10 to −12	White-blue with green-red halo	—	—
	Pistoia, Italy (43.93° N, 10.96° E)	From zenith to Sagittarius toward moon, near Vega in cygnus	5 s	−10 to −11	Blue-green	—	—
P. Fapperdue	Viterbo, Italy (42.40° N, 12.10° E)	From 50° altitude NNE to SW horizon	10 s	−17.5	Orange; fragmentation with some parts becoming white, mag −1	Diameter of the moon (30 min)	Persistent for 2–3 s
	Nepi, Italy (42.23° N, 12.35° E)	NE sky to W horizon	—	−13	—	—	—
	Rome, Italy (41.9° N, 12.5° E)	NE sky to W horizon	3 s	−15	Central part white	—	Irregular over 20°–30°, red-green color

None of the observers reported any sounds.

Western Czechoslovakia, January 30, 223230 GMT. The following is a report from Zdeněk Ceplecha.

A fireball of −8 maximum absolute magnitude was photographed by two Czech stations of the European network. The fireball traveled a 34-km luminous trajectory in 2.4 s. The following data resulted from the two photographic records.

	Beginning	Maximum Light	Terminal
Velocity, km/s	16.2	14.9	6.3
Height, km	69.3	46.4	37.2
Latitude	50.312° N	50.24° N	50.212° N
Longitude	16.328° N	16.28° E	16.258° E
Magnitude	−2.7	−8.0	−2.3
Mass, kg	2.1	1.0	None
Z R	20.8°	—	20.9°

Fireball type: II
Meteorite fall very improbable.

Radiant, 1950.0	Observed	Geocentric	Heliocentric
Alpha	146.7°	150.1°	—
Delta	67.9°	70.8°	—
Lambda	—	—	52.4°
Beta	—	—	16.3°
Initial Velocity, km/s	16.28	11.81	33.75

Orbit, 1950.0	
A	1.341 AU
E	0.327
Q	0.903 AU
Aphelion	1.78 AU
Omega	228.6°
Ascending Node	310.532°
Inclination	16.6°

Meteor Shower: Early member of Camelopardalids not quite excluded.

Information contact: Same as for Austria.

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Applications are due April 30, 1981. Inquiries, nominations, and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma is an equal opportunity employer.

Seismologist: University of Utah. The University of Utah is expanding its geophysics program in the Department of Geology and Geophysics by adding a tenure track faculty member in seismology at the assistant to associate professor level. Applicants with backgrounds and specialities in seismic imaging and theoretical seismology will be given preference. The individual will be expected to teach undergraduate and graduate courses, and to pursue an active research program with graduate students.

The department has modern teaching and research programs in geology and geophysics, and has close associations with the numerical analysis and data processing groups in computer science, electrical engineering, and mathematics. The geophysics component of the department has strong research and teaching programs in electrical and electromagnetic methods, thermal properties of the earth, potential fields, and seismology. Current research in seismology includes: earthquake research utilizing a new PDP 11/70 computer; monitoring of the Intermountain seismic belt by a 55 station telemetered network utilizing a new on-line PDP 11/34 computer; major experiments in seismic refraction and reflection profiling for crustal structure, and allied research in tectonophysics of mountain building.

The closing date for applications is May 1, 1981 and the appointment date is September 1981. However, the search may be extended if a suitable candidate is not selected, in which case applicants for a one-year visiting position for the academic year 1981–82 will also be considered.

A Ph.D. is required for this position.

Applicants should submit a vita, transcripts, a letter describing his/her research and teaching goals, and names of five persons for reference. Qualified persons should send their applications to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112.

University of Utah is an equal opportunity/affirmative action employer.

Meteorology Studies Program Coordinator. The University of North Dakota anticipates offering an undergraduate degree in Meteorological Studies beginning the fall semester 1981. This program will be very applications oriented, and will include courses in dynamics, synoptics, radar meteorology, cloud physics meteorology, and forecasting among others. This co-sponsored program requires 40 hours for a major, plus twelve hours of calculus and twelve hours of physics, and will utilize to a great degree the research staff and facilities in the co-sponsoring departments of aviation and geography.

The coordinator's position will include general overall administrative responsibility for the program on a day to day basis, teaching of courses in synoptics, dynamics, and radar meteorology as well as being the primary student advisor for the program. Additionally, the position offers an excellent opportunity to be involved in research associated with the department of aviation's multi-year, multi-million dollar research contracts. Facilities include a Citation II jet cloud physics aircraft, a Cheyenne turboprop research aircraft, a Blanik glider, a 5 cm digital weather radar, and a dedicated computer facility.

The position is a 12 month non-tenured appointment within the department of aviation beginning 1 July 1981. The position requires a Ph.D. in meteorology and a strong background in teaching. A specialization in radar meteorology is preferred. Salary is commensurate with experience ($25,000–$35,000).

The Department has experienced phenomenal growth in academics and research these past years, and encourages applicants to send their resumes by 1 June 1981 to: Dr. Patrick J. Brady, Department of Aviation, Box 8216—University Station, Grand Forks, ND 58202. The University of North Dakota offers an attractive benefits package, retirement plan, and excellent working conditions.

UND is an equal opportunity employer.

University of Hawaii. The Hawaii Institute of Geophysics and the Department of Geology and Geophysics of the University of Hawaii invite applications for tenure track positions available July 1, 1981. Applicants with specialties in any of the following fields will be given consideration:

1. Marine geophysics with emphasis in marine gravity and tectonics
2. Marine seismology
3. Marine magnetics

Applicants should have a Ph.D. degree and a demonstrated ability to conduct and promote marine research. Ability to teach at all levels is required. The position will be a joint one on an 11-month basis between the Hawaii Institute of Geophysics and the Department of Geology and Geophysics. The appointments will be at the rank of assistant professor.

Apply with resume and names of three references to Charles E. Helsley, Director, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii 96822. Closing date is May 15, 1981.

The University of Hawaii is an affirmative action and equal opportunity employer.

Ground-water Geophysicist

Woodward-Clyde Consultants, a geosciences and engineering consulting firm, has an immediate opening in its Orange, California office for a ground-water geophysicist. This position will be in association with a 25-person interdisciplinary Water Resources Section headquartered in San Francisco.

Responsibilities

The successful candidate will participate in geophysical aspects of hydrogeological studies, business development, peer and project review, and project management.

Requirements

A minimum of a MS plus 2-3 years experience, -or- PhD, in both theoretical and applied aspects of ground-water geophysics. Project management and business development experience preferred.

Send resume with references by April 30, 1981 to:
David A. Stephenson, Chief
Water Resources Section

Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700
San Francisco, California 94111

We are an Equal Opportunity Employer

South Dakota School of Mines & Technology. The Department of Geology and Geological Engineering anticipates two tenure track positions in economic geology beginning fall 1981 (1) Crystal chemistry mineralogy petrology of igneous and metamorphic rocks with emphasis on mineral deposits (2) Geology of strata-bound or hydro-thermal deposits. Number one is at the full professor level, number two at the assistant or associate professor level. Please send resume and three letters of reference to Alvis Lisenbee, Department of Geology and Geological Engineering, South Dakota School of Mines & Technology, Rapid City, SD 57701 (605-394-2461).

South Dakota School of Mines is an equal opportunity/affirmative action employer.

Purdue University. A tenure track appointment in the area of surveying and mapping. Undergraduate teaching in the areas of basic surveying, adjustment computations, and introductory photogrammetry photo interpretation. Involvement in teaching graduate level courses, and in existing and new research programs.

Preferential consideration to candidates with a Ph.D. and land surveying registration (or in the process of getting such degree and registration). Rank and salary are open and depend on the experience and qualifications of the applicant.

Send resumes, by 15 April 1981, to Head, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

Purdue is an equal opportunity/affirmative action employer.

Structural Geologist. The Department of Geophysical Sciences invites applicants for a tenure track structural geology position at the assistant or associate professor level, beginning August 1981. Ph.D. required. Salary commensurate with experience and qualifications.

Departmental equipment includes a digitizer, various geophysics equipment, and a remote sensing laboratory with an edgewise enhancer. The candidate will have the opportunity to substantially add to his or her equipment needs. Present computer facilities include a DEC 10 and IBM 360-44, while PK 3240 system with 16 megabyte capacity is under development.

ODU is a state-supported university serving nearly 15,000 students and is situated within the seven-city Hampton Roads metropolitan area that is nationally known for its historic, recreational, and cultural facilities.

Send vitae, a brief discussion of research interest, and arrange to have three letters of reference by May 1, 1981 to Dr. Dennis A. Darby, Chairman, Department of Geophysical Sciences, Old Dominion University, Norfolk, VA 23508.

An affirmative action/equal opportunity employer.

Texas Tech University: Faculty Positions. The Department of Geosciences is seeking applications for additional faculty members in geology, geophysics and geochemistry; applicants from all fields of geology other than paleontology will be given serious consideration.

These are tenure track positions at the assistant professor level with appointments starting September 1, 1981.

Applicants must have completed their doctoral programs, be interested in teaching at both the undergraduate and graduate levels, and have specific plans for research in their fields of specialization.

Applicants for the positions should submit resumes, the names of at least three persons from whom the department may request letters of recommendation, and brief description of research interest to:

Donald R. Haragan, Chairman
Department of Geosciences
Texas Tech University
P.O. Box 4109
Lubbock, Texas 79409

Texas Tech University is an equal opportunity/affirmative action employer.

Professor/Oceanography. The Department of Oceanography of Texas A&M University invites applications for an academic faculty position. The appointment is expected to be made at the level of professor in one of the major sections of the Department—biological oceanography, chemical oceanography, geological and geophysical oceanography, or physical oceanography.

Hence, applications are solicited from individuals who have demonstrated scholarship in research and teaching in any oceanographic subdiscipline. Outstanding applicants suitable for appointment to academic ranks other than professor will also be considered, but preference will be given to applicants suitable for appointment to the higher ranks.

To apply, or for further information, please contact Professor R. O. Reid, Head, Department of Oceanography, College Station, TX 77843 (713/845-7211).

Texas A&M University is an affirmative action/equal opportunity employer.

Geological or Mining Engineer. Geological or Mining Engineer with Ph.D., versatility and capability to integrate with geoscientists, oceanographers and ocean engineers. Permanent full-time teaching-research position with rank and salary open. Send resume and names of three references to: N. W. O'Hara, Head, Department of Oceanography & Ocean Engineering, Florida Institute of Technology, Melbourne, FL 32901 (305) 723-3701 x302.

Equal opportunity employer.

Petrology/Geochemistry, University of New Brunswick. The Department of Geology has a tenure track position available from 1 July, 1981, at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students. This position is in addition to one currently advertised for a rock mechanic or geochemist.

The applicant should have a background in petrochemistry and petrology and should be prepared to teach in some aspects of petrology and geochemistry. The successful applicant will be responsible for supervision of analytical facilities including an XRF.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3

DIRECTOR

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY of COLUMBIA UNIVERSITY

Columbia University invites applications and nominations for the Directorship of Lamont-Doherty Geological Observatory. The director must be capable of exerting strong intellectual leadership in the Earth Sciences. Scholarly eminence and capabilities in administration, future planning, and fund raising are required.

Responsibilities of the director are directed toward enabling L-DGO to maintain its position as a leading institution in its field. To this end, the director will be responsible for overall administration of the Observatory, ongoing scientific research, formulation of new research directions, and fund raising.

L-DGO is an institute of Columbia University dedicated to graduate education and research in the Earth Sciences. Founded in 1949, the Observatory has ongoing programs in marine geology and geophysics, seismology, geochemistry, physical oceanography, paleoclimatology, atmospheric and space sciences, petrology, paleomagnetics, stratigraphy, structural geology, tectonophysics, and marine biology. The Observatory is located in Palisades, New York, one-half hour from the main campus of the university. Research programs are supported by government contracts and grants in excess of $15,000,000 annually and by endowments and industry. About 110 graduate students in the Department of Geological Sciences conduct their research at the Observatory.

Applications or nominations should be submitted by May 15 to:
Dr. Lynn R. Sykes, Chairman
Search Committee
Lamont-Doherty Geological Observatory of Columbia University
Palisades, New York 10964

Columbia University is an equal opportunity/affirmative action employer.

Head: Earth Resources Branch, NASA/Goddard Space Flight Center. GS-1330-14/15: $37,871–$50,112 per annum, full-time permanent. The Earth Survey Applications Division, Applications Directorate, NASA/Goddard Space Flight Center invites applications for the open position of Head, Earth Resources Branch. The incumbent of this position is responsible for planning, managing, and conducting broad programs in earth resources remote sensing basic and applied research and data analysis, emphasizing the development and demonstration of applications of remote sensing of earth resources from earth orbiting satellites. The primary areas of research in the Branch are land use management, vegetation science including agriculture/forestry/rangeland and environmental monitoring utilizing remotely sensed data and advanced technologies. Also, significant effort is dedicated to sensor data evaluation in terms of applications and scientific utility, and to specification of data acquisition and information extraction systems which best meet user scientific and resource management needs. An advanced degree in earth or physical sciences is required with education in the vegetation sciences, land use or environmental monitoring being specifically preferred. Candidates should also have several years of progressively more responsible experience in the conduct, guidance and management of remote sensing research programs and clear evidence of a strong research background indicating senior research scientist stature.

Resumes/SF 171's should be sent to:
Dr. Robert D. Price, Assistant Chief
Earth Survey Applications Division
Code 920
Goddard Space Flight Center
Greenbelt, MD 20771
Deadline for applications is April 30, 1981.

Paleontologist. Seek half-time visiting professor for academic year 1981–82 to teach introductory course in paleontology and seminar of own choosing. Appointment is for half-time for entire academic year or full time for fall semester. Ph.D. required. Rank and salary negotiable. Inquiries to: Paul C. Hess, Chairman, Department of Geological Sciences, Brown University, Providence, RI 02912. Deadline for applications is May 31, 1981.

An equal opportunity and affirmative action employer.

Assistant Professor, Hydrology/Water Resources. Tenure track appointment involving teaching and research in hydrology and water resources. Excellent opportunities for interdisciplinary collaboration with ecologists, meteorologists, geologists and hydrologists. Please call or send resume, reprints, and names of three references to George M. Hornberger, Department of Environmental Sciences, Clark Hall, University of Virginia, Charlottesville, Virginia 22903.

Closing date for applications April 15, 1981.

The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

Hydrogeologist. Applications invited for a permanent faculty position. The position requires a Ph.D., teaching at graduate and undergraduate levels, supervision of research, and research in area of specialty. Interaction with faculty in surface water hydrology, stable-isotope geochemistry, geophysics, and sedimentary geochemistry is expected.

Candidates should send resume, statement of research interest, and addresses of three references to L. D. McGinnis, Chairman, Department of Geology, Northern Illinois University, DeKalb, IL 60115.

An equal opportunity/affirmative action employer.

Director: Meteorology Division, Air Force Geophysics Laboratory. Air Force Geophysics Laboratory invites applications for the position of Director of the Meteorology Division located at Hanscom Air Force Base, Massachusetts. The Division is responsible for Air Force research and development in meteorology, atmospheric physics, remote and direct sensing technology, climatology, and relative technologies. The division director provides overall direction to an R&D program which employs over 80 people and covers a broad range of in-house and contractual scientific investigation. A candidate should have a record of distinguished achievement in meteorology/atmospheric physics as a research scientist and manager of a substantial R&D unit. This position is Air Force Senior Executive Service with a salary range of $52,247 to $57,673, subject to current $50,112 ceiling. For an application package, call collect: Robert Ellerin, (617) 861-2896. To be considered, applications must be returned by 30 April 1981.

Equal employment opportunity employer.

Visiting Assistant Professor. One-year, temporary position available August 1981 to teach mineralogy, general geology, and perhaps optical mineralogy. The successful candidate will be required to teach three courses during a two-semester year; someone who enjoys teaching is needed. Persons on leave are encouraged to apply. Deadline for applications is April 17, 1981. Please send resume to David Krinsley, Department of Geology, Arizona State University, Tempe, AZ 85281.

ASU is an equal opportunity employer.

Chemical Oceanography/Marine Geochemistry. Anticipated faculty opening at Florida State University. Applicants from all specialties welcome—preference to candidates who enhance existing programs in marine and atmospheric chemistry, sedimentary geochemistry and radiochemistry. Contact, Chairman/Chemical Oceanography Search Committee, Department of Oceanography, The Florida State University, Tallahassee, FL 32306. Telephone 904/644-6700.

Princeton University/Scientific Programmers and Data Analysts. The Geophysical Fluid Dynamics Program of Princeton University seeks applicants for two full time scientific programming positions that may become available in July 1981. These programmers will become part of a research group that is making use of measurements of a variety of chemicals in the world oceans to learn about oceanic circulation and mixing. One position involves data analysis and the other involves developing computer simulations.

Applicants should have a bachelor's or master's degree in oceanography, physics, chemistry or engineering with a strong math background. Fortran programming and course work in oceanography are required.

Salary is $15,000 to $17,000 per year.

Send a resume, course transcript and names of 3 references to Prof. Jorge L. Sarmiento, Director, Geophysical Fluid Dynamics Program, Princeton University, Princeton, NJ 08544.

Princeton University is an equal opportunity/affirmative action employer M/F.

Faculty Position in Oceanography/Geology: University of Northern Colorado. The Department of Earth Sciences invites applications for a full-time, tenure track faculty position in oceanography, starting September 1981. We are seeking a person with a broad background in oceanography and one or more of the related earth science fields such as marine geology and/or sedimentology. Major responsibility will be teaching beginning and advanced courses in oceanography, courses in the related field, and general education courses. A modest amount of research is possible and is encouraged. Applicants should possess the Ph.D. degree or be in the final stages of completion of that degree. Starting rank and salary will depend on experience and other qualifications of the candidate selected.

Applicants should submit a resume and at least three letters of recommendation to Dr. L. Glen Cobb, Chairman, Department of Earth Sciences, University of Northern Colorado, Greeley, CO 80639.

The deadline for application is May 10.

COURSES

Course No. 401: Inversion Methods in Remote Sensing, Alexandria, VA. MAY 19–22, 1981. The course is intended to provide a basic understanding of the concepts and an overview of applications of the increasingly important field of inversion methods in remote sounding and is structured to benefit those involved in the theoretical, experimental, data analysis, and management aspects of remote sensing experiments to monitor the atmospheric constituents and properties from ground, airborne, or space platforms. The advantages, limitations, and future prospects of each technique will be discussed. Instructors will be Drs. M. Chahine, B. J. Conrath, A. Deepak, B. M. Herman, W. L. Smith, D. H. Staelin, and E. R. Westwater. Registration fee is $460.00.

A Certificate of Course Completion will be awarded to those who complete each course. For further information, contact: Nancy Reynolds or Sue Crotts, Course Coordinators, IFAORS, P.O. Box P, Hampton, Virginia 23666 (Tel: 804/827-5811).

STUDENT OPPORTUNITIES

Meteorology and Physical Oceanography Assistantships. Research assistantships for graduate students in meteorology and physical oceanography are available from The Florida State University. Research topics may cover atmospheric dynamics, physical meteorology, synoptic meteorology, climatology, numerical weather prediction, physical oceanography, chemical oceanography, ocean modelling, satellite oceanography and geophysical fluid dynamics

Appointments are half-time and offer salaries up to $10,500 per year. Beginning graduate students may be offered salaries as low as $7,200 Students with undergraduate degrees in physics, chemistry, mathematics, statistics, meteorology, oceanography and engineering are encouraged to apply.

Additional information may be obtained from Dr. James J. O'Brien, Mesoscale Air-Sea Interaction Group, The Florida State University, Tallahassee, Florida, 32306.

SUPPLIES

Rock Hammer with pick head and leather holster for $16.00. This is $6.00 below list price. Write for free catalog "Geologic Field Supplies and Prospecting Equipment". Western Heritage, 101 S Washington St., Hinsdale, IL 60521. Telephone (312) 964-5228.

Meetings

AGU Front Range Branch 'Hydrology Day'

The AGU Front Range Branch is sponsoring a HYDROLOGY DAY on Thursday, April 23, 1981 at Colorado State University in Fort Collins, Colorado.

All sessions are in the Student Center.

Session 1 Student Papers 8:15–10:15
Duane HAMPTON (Ph.D.) Mechanisms of Coupled Heat and Water Transport in Unsaturated Porous Media,
Jayantha T. B. OBEYSEKERA (Ph.D.) Physically Based Stochastic Models for Seasonal Streamflow
Roy W. KOCH (Ph.D.) A Physically Based Derivation of the Distribution of Excess Precipitation
Francisco N. CORREIA (Ph.D.) A Rainfall-Runoff Model Using a Generalized Unit Hydrograph Theory and Modern Infiltration Theory
Session 2 Student Papers 8:15–10:15
Thomas W. ANZIA (senior) A Comprehensive Table of Standard Deviates for Confidence Limits on Extreme Events
Victor NAZARETH (M.S.), Aquifer Properties from Single-Hole Aquifer Tests
Jim HYRE (M.S.), Experimental Investigation of Ponding Time and Soil Water Content Evolution
Andres CARDENAS (M.S.), A Conceptual Model for Predicting Monthly Streamflows
Session 3 Professional Papers 10:30–12:00
Comparison between Overland Flow Model and Experimental Data, D. D. Adrian and C. J. Martel
Livestock Grazing Management and Nonpoint Source Water Quality Assessment, Eric B. Janes
Rainfall Simulation to Determine Grazing Management Effects on Upland Hydrology, P. L. Gustafson, R. P. Julander and E. B. Janes
LUNCHEON: Speaker, Dr. Jeris A. Danielson
Session 4 Professional Papers 1:15–5:00
Repeat Measure Analysis of Variance of Rainfall Simulation Plot Hydrologic Response, S. D. Hudson, P. L. Gustafson and E. B. Janes
Work of Water and Power Resources Service in the Application of Remote Sensing to Water Resources Investigations, Jim Verdin
Multivariate Models of Residential Water Demand: A Case Study of Denver, Colorado and Its Metropolitan Area" Clive Jones and John Morris
A Dilemma: Too Much Water in a Denver Development, Jim John
Prediction of Natural and Man-Induced Bedload Transport in Steep Western Streams, Donald H. Simpson and Donald O. Doehring
Hydrologic and Hydraulic Analysis of the Middle Rio Grande, Robert Simons
An Approach for the Detection of Changes in Water Quality Variables, R. W. Koch and T. G. Sanders
Run and Range Properties of Shifting Level Models, J. T. B. Obeysekera, J. D. Salas and D. C. Boes

For registration and transportation information, contact H. J. Morel-Seytoux, A305 Engineering Research Center, Colorado State University, Fort Collins, Colorado 80523. Phone (303) [illegible]
Transportation is being arranged from Denver, Boulder, Golden, and Laramie.

New Listings

1981

June 22–26 International Symposium on Erosion and Sediment Transport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Erosion, National Research Council of Italy. (P. Tacconi, Secretary of the Organizing Committee, Istituto di Ingegneria Civile Via S. Marta, 3 50139 Firenze, Italy.)

June 29–July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

Nov. 9–20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography (R. Omandi, Survey of Kenya, P.O. Box 30046, Nairobi, Kenya.)

1982

Apr. 11–16 Penrose Conference on Antarctica, Shenandoah National Park, Va. Sponsor, GSA. (Ian W. D. Dalziel, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964.)

Aug. 22–28 Third Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii. Sponsor, IUGS (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101.)

Information on the IAGA Edinburgh Assembly

The Fourth General Scientific Assembly of IAGA will be held in Edinburgh, Scotland, U.K., from 3 to 15 August 1981, in response to the invitation from the Royal Society of London through its National Subcommittee for Geomagnetism and Aeronomy. H.R.H. The Prince Philip, Duke of Edinburgh, Chancellor of the University of Edinburgh, has graciously consented to act as Patron of the Assembly.

The First Circular was sent out in February 1980 to all IAGA News recipients over the world. A great number of "Pre-Registration" (about 500) has been received by the Local Organising Committee (chairman: B.R. Leaton).

The Second Circular has been sent with a Registration Form from the Local Organising Committee directly to those who responded to the First Circular. The Second Circular contains the important information and remarks concerning Venue (the Assembly will be held in Appleton Tower, one of a complex of the new buildings of the University of Edinburgh, a half km south of Old College and about 1 km south of the city centre); Climate; Transport to and in Edinburgh; Pre-Assembly Excursion; Assembly Excursions; Social Tours; Social Programme; Accommodation; Registration; Insurance; Currency; Sports Facilities; Edinburgh International Festivals of Music, Dance and the Arts; Provisional Schedule for Scientific Meetings.

REGISTRATION FEE

Delegate: 46 Pounds (if received before 30 April 1981)
56 Pounds (if received between 30 April and 25 July, 1981)
70 Pounds (if received after 25 July 1981)
Accompanying Members: 22 Pounds each
Student: 25 Pounds

There is no separation of registration fee for one or two week participation. However, the Local Organising Committee will consider favourably that genuine IAMAP members staying one week at the IAGA Assembly will get some refund on the full registration fee at Edinburgh.

Those who are intending to participate in the IAGA Edinburgh Assembly but do not yet have the *Second Circular and Registration Form*, are advised to write a request for these to

Dr. S.R.C. Malin
Secretary, Organising Committee for IAGA Assembly
Geomagnetism Unit, Institute of Geological Sciences
Murchison House, West Mains Road
Edinburgh EH9 3LA, Scotland, U.K.

SUMMARY OF SESSIONS FOR THE IAGA EDINBURGH ASSEMBLY

Code	Number of Half-days	Proposed Session Title	Proposed Convenors	Sponsoring Bodies
11	3	Scientific results from the MAGSAT missions: main field	R.A. Langel, D.R. Barraclough	Divs. I, III, V
12	1	Mathematical modelling of the main geomagnetic field (A.N. Pushkov memorial session)	H.W. Paddie	I, III
13	2	The magnetohydrodynamics of planetary interiors	D.E. Loper	I
14	1	Electromagnetic induction studies in the oceans and their implications for sub-oceanic layers	C.S. Cox	I
15	1	Audiofrequency magnetotellurics and crustal studies using ELF wave propagation	D. Strangway, S.E. Hjelt, V.R.S. Hutton	I, III
16	1	Regional electromagnetic induction studies	[illegible], J. Jankowski	I
17	2	Physical parameters related to geomagnetic anomalies (permanent or time-dependent)	[illegible], C.C. Weber, C.G.A. Harrison	I
18	1.5	Time scales of geomagnetic secular variation	C.E. Barton, P. Tschulle	I
19	2	Paleomagnetic aspects of the evolution of the Mediterranean and North Atlantic region	J.D.A. Zijderveld, R. Van der Voo	I
1ID	2	Magnetic reversal stratigraphy, including studies of polarity transitions	W. Lowrie, A.N. Khramov	I
111	2	Properties of natural and synthetic titanomagnetites	G.N. Petrova, M. O'Reilly	I
112	2.5	Physical and chemical processes of magnetic overprinting in relation to geological events	I. Hedley, F. Heller, D.J. Dunlop	I
113	1.5	Effects of stress on the magnetic properties of rocks and minerals	J.P. Hodych, H. Evsen, H. Jelenska	I
2S	2	High latitude ionospheric irregularities and small-scale structures	S.M. Ossakow, A. Brekke	II, III
2C	1	Atmospheric phenomena linked with polar cusps	M.H. Rees	II, III
2D	4	Dynamics of thermospheres and exospheres of the earth and planets	P. Bauer, A.F. Nagy, C.A. Reddy	II, URSI, COSPAR
2A	2	Auroral emission: X ray, ultraviolet, visible and infrared	A. Vallance-Jones, R.R. Meier, B.N. Shefov	II
2M	7	Middle Atmosphere Scientific Symposia I [including (a) neutral and ion chemistry, (b) airglow, (c) water vapor in mesosphere, (d) noctilucent clouds, (e) solar fluxes especially UV and X rays, (f) electrodynamic coupling, (g) energetic particle effects, (h) laboratory aeronomy]	L.R. Megill	IAMAP/ICMUA Middle Atmos Com.

Code	Number of Half-days	Proposed Session Title	Proposed Convenors	Sponsoring Bodies
3S	1	Special symposium on Saturn	V.M. Vasyliunas	III, I, II, IV COSPAR
3T	2	Theory of planetary magnetospheres	G.L. Siscoe, A.A. Galeev	III
3A	1	Acceleration processes	R.L. Dowden, P.J. Palmadesso	III URSI/IAGA
3AP	1	EM wave particle interactions	W.J. Hughes	III URSI/IAGA
3I	2	Role of ion composition in understanding magnetospheric processes	R.G. Johnson	III
3L	1	Characteristics and large-scale structure of Pi2 pulsations	W.J. Hughes	III
3P	2	The physics of pulsation resonance regions	W.J. Hughes	III
3Q	2	Quantitative comparisons of magnetospheric event data and models	W.P. Olson	III
3M	3	Polar cusp and magnetosphere boundary layers	G. Haerendel	III
3C	1	Polar cap phenomena	C.T. Russell	III
4L	2	Large-scale structure and evolution of the solar wind	D.S. Intriligator, H. Schwenn	IV
4K	2	Kinetic physics and plasma turbulence in the solar wind	H. Dobrowolny	IV
4B	1	Solar wind during solar-maximum period	M.H. Acuna, F. Mariani	IV
4Q	1	Origin and composition of the solar wind	K.I. Gringauz, W.I. Axford	IV
VV	2	Workshop on observatory and repeat station practice	G. Fischer	V
VC	2	Comparisons of analytical techniques for national and regional magnetic charts	[illegible]	V, I
VK	3	Production of regional magnetic charts using recent satellite data	[illegible]	V, I
AR	1	Recent results from magnetic and aeronomic research in Antarctica	[illegible]	AR, II, III
HI	1	Geomagnetism and aeronomy — the historical perspective	[illegible]	HI
EI	2	Representation of magnetospheric and ionospheric source fields and their induction effects	[illegible]	EI, II, III
EN	1	Effects of source characteristics on electromagnetic induction	J.F. Hermance	EI, II, III
XI	1	Induction risk	W.H. Campbell	EI, II, III
EM	1	Solar and lunar external and internal magnetic variations, and related phenomena	J.C. Gupta, D.E. Winch	EI, II, III

Code	Number of Half-days	Session Titles (or Working Group Meetings)	Convenor(s)
R1	1	Reporter Review Session of IAGA Division I	Division Chairmen
B1	0.5	Business Meeting of IAGA Division I	Division Chairmen
R2	1.5	Reporter Review Session of IAGA Division II	Division Chairmen
B2	0.5	Business Meeting of IAGA Division II	Division Chairmen
R3	1.5	Reporter Review Session of IAGA Division III	Division Chairmen
B3	0.5	Business Meeting of IAGA Division III	Division Chairmen
R4	1.0	Reporter Review Session of IAGA Division IV	Division Chairmen
B4	0.5	Business Meeting of IAGA Division IV	Division Chairmen
RV	1.5	Reporter Review Session of IAGA Division V	Division Chairmen
BV	1	Business Meeting of IAGA Division V	Division Chairmen
G1	1	General contributions to IAGA Division I	D.I. Gough
G2	1	General contributions to IAGA Division II	H. Fischbach, A.D. Danilov
G3	2	General contributions to IAGA Division III	A. Nishida
G4	0.5	General contributions to IAGA Division IV	L.F. Burlaga
GV	0.5	General contributions to IAGA Division V	C.G. Suckadorff

Scheduled Evening Meetings of Working Groups or Interdivisional Bodies

AP	*Interdivisional Commission on Antarctic Research*
HI	*Interdivisional Commission on History*
MA	*Interdivisional Commission on the Middle Atmosphere*
EI	*Interdiv. WG on Relations between External and Internal Mag. Variations*
I-1	*Working Group I-1. Analysis of the Main Field and Secular Variations*
I-2	*WG I-2. Theory of Planetary Magnetic Fields and Secular Variations*
I-3	*WG I-3. Electromagnetic Induction and Electrical Conductivity*
I-4	*WG I-4. Magnetic Anomalies*
I-5	*WG I-5. Palaeomagnetism*
I-6	*WG I-6. Rock Magnetism*
III-1	*WG III-1. ULF Pulsations*
III-2	*WG III-2. Composition of Hot Magnetospheric Plasma*
III-3	*WG III-3. Quantitative Magnetospheric Models*
V-1	*WG V-1. Geomagnetic Observatories, Instruments and Standards*
V-2	*WG V-2. Meteor Observations*
V-4	*WG V-4. Optical Calibration Standards*
V-5	*WG V-5. Magnetic Surveys and Charts*
V-6	*WG V-6. Geophysical Indices*
V-7	*WG V-7. Collection and Dissemination of Data*
V-10	*WG V-10. Ground-Based Measurements for Satellite Geomagnetic Surveys*
AO	*Joint WG (IAGA Divs. II & III): Auroral Oval and Its Extension into Space*
SD	*IAGA/URSI Joint WG: Structure and Dynamics of the Thermosphere, Ionosphere and Exosphere*
NI	*IAGA/URSI Joint WG: Neutral and Ion Chemistry and Solar Fluxes*
PE	*IAGA/URSI Joint WG: Passive Electromagnetic Probing of the Magnetosphere*
WI	*IAGA/URSI Joint WG: Wave Instabilities in Space Plasmas*

Seminar for Developing Countries: see page 46.

Remark: Some other informal meetings will be held if such requests are received in advance and rooms are available. Please contact with the Local Organising Committee.

PROVISIONAL SCHEDULE OF THE IAGA EDINBURGH ASSEMBLY

[illegible]

1981 AGU Spring Meeting

Baltimore, the site of the AGU Spring Meeting, May 25–29, is enjoying a major urban renaissance. Nowhere is this more apparent than in Metro Center, the 1000-acre downtown core of Baltimore. The convention center, an ultramodern meeting facility, is only a short walk from Harbor Place. Harbor Place is a skylighted, terraced conglomeration of more than 20 waterside restaurants and over 100 boutiques.

Hotel Accommodation. A block of rooms is being held at three nearby hotels; the Baltimore Hilton, the Lord Baltimore, and the Holiday Inn-Downtown. The Lord Baltimore and the Hilton are connected by a covered walkway. Read the housing application and MAIL THE COMPLETED APPLICATION FORM TO THE HOUSING BUREAU early to insure confirmation of preferred hotel.

Registration. Everyone who attends the meeting must register. Preregistration (received by May 8) saves you time and money, and the fee will be refunded if AGU receives written notice of inability to attend by May 15. Registration rates are as follows:

	Preregistration	At Meeting (after 5/8)
Member	$45	$60
Student Member	$25	$40
Nonmember	$65	$85

Registration for 1 day only is available at one half the above rates. Members of the American Meteorological Society, the American Society of Photogrammetry, and the American Congress on Surveying and Mapping may register for the meeting at the AGU member rates.

Students who are not AGU members should send in an application form with their registration payment. The difference between member (or student member) registration and nonmember registration may be applied to AGU dues if a completed membership application is received at AGU by August 3, 1981. Current AGU annual membership rates are: $20 members; $7 student members.

To preregister, fill out the registration form, and return it with your payment to the AGU Office. When payment is made by an organization, please attach the form wherever possible; or be certain that your name and other pertinent information is on the check. Your receipt will be included with your preregistration material at the meeting. Preregistrants should pick up their registration material at the preregistration desk at the Convention Center. (On Sunday, from 5–8 P.M. in the lobby of the Hilton hotel).

The program and meeting abstracts will appear in the April 28 issue of *Eos*, which is mailed to all members in advance of the meeting.

Complimentary badges for guests not attending the scientific sessions will be available at the registration desk.

Social Events

An array of evening activities includes the Ice Breaker on Monday; the awards presentation honoring fellow scientists at a ceremony open to all participants, followed by a reception, on Tuesday; and an evening of fun and exploration on Thursday at the Maryland Science Center.

Business Luncheons

There will be eight section luncheons; Geodesy, Geomagnetism and Paleomagnetism, Hydrology, Oceanography, Planetology, Seismology, Solar-Planetary Relationships, and Volcanology, Geochemistry and Petrology. (space is limited)

Wednesday, May 27, 1981

			Time
Geodesy			
	Place	Chiapparelli's Restaurant 237 South High Street	noon
Hydrology			
	Place	Caesar's Den 223 South High Street	12:15
Oceanography			
	Program:	"The Impact of Satellites on Future Oceanographic Research" W. Stanley Wilson, NASA	
	Place	Velleggia's Restaurant Corner of Pratt & Albemarle Street	noon
Planetology			
	Place	Trattoria Petrucci 300 South High Street	12:30

Thursday, May 28, 1981

Seismology			
	Program:	A Scientific Talk: "Reference Earth Model and Beyond" Adam M. Dziewonski, Harvard University, and Don L. Anderson, California Institute of Technology	
	Sponsor	Kinemetrics, Inc. Teledyne Industries Inc. W.F. Sprengnether Instrument Co., Inc.	
	Place	Antonio's Restaurant 925 Eastern Avenue	noon
Solar-Planetary Relationships			
	Program	Role of AGU in Politicizing Public Policy for Science (tentative) Ned A. Ostenso, Chairman, AGU Public Affairs Committee	
	Sponsor	Martin Marietta Aerospace, Denver Division	
	Place	Velleggia's Restaurant Corner of Pratt & Albemarle Street	11:45
Geomagnetism and Paleomagnetism			
	Place	DeNittis Restaurant 906 Trinity Street	12:45
Volcanology, Geochemistry, and Petrology			
	Place	Sabatino's Restaurant 901 Fawn Street	noon

Check the appropriate spaces on the registration form and indicate number of reservations. Details of these activities will be published April 28th in the abstract issue of EOS. *Follow* the Sail Into Baltimore update.

PROGRAM SUMMARY

Union
Climate Variability (Monday PM)
Voyager I Saturn Results (Wednesday AM)
History of Space Research (Wednesday PM)
Ground-Water Quality (Thursday PM)
Io (Thursday PM)

Special Sessions
Decade NA Geology (GSA) (Monday PM)
Overview of NSF Programs (Tuesday PM)

Geodesy
Seasat-Geodesy (Wednesday AM)
Geodesy I (Thursday AM)
Geodesy II (Thursday PM)
Geodesy III (Friday AM)

Geomagnetism and Paleomagnetism
Tertiary Paleomagnetism (Monday AM)
Paleomag/Megatectonics (Monday PM)
Em Induction I (Tuesday AM)
EM Induction II (Tuesday PM)
Magsat-I (Wednesday AM)
Magsat II (Wednesday PM)
Paleozoic/Precambrian (Wednesday PM)
Geomagnetic Fluctuations (Thursday AM)
Magnetization Processes I (Thursday AM)
Magnetization Processes II (Thursday PM)

Hydrology
Efficacy in Modeling (Monday AM)
Acid Rain (Monday PM)
General Surface Water (Monday PM)
Urban Runoff I (Tuesday AM)
Desertification (Tuesday AM)
Urban Runoff II (Tuesday PM)
Water and Synthetic Fuels (Tuesday PM)
John Ferris Symposium I (Wednesday AM)
John Ferris Symposium II (Wednesday PM)
Drinking Water and Health (Wednesday PM)
Organics in Ground Water (Thursday AM)
Geochem and Water Quality (Thursday PM)
General Groundwater (Friday AM)

Meteorology
SEASAT-Meteorology (Monday AM)
Atmospheric Chemistry I (Tuesday AM)
General Meteorology (Wednesday PM)

Oceanography
Seasat Oceanography I (Monday PM)
Seasat Oceanography II (Tuesday AM)
Paleo-Oceanography (Tuesday AM)
Seasat Oceanography III (Tuesday PM)
Chemical Traces (Tuesday PM)
Shelf Circulation (Wednesday AM)
Marine Sediments (Wednesday AM)
Deep Ocean Currents (Wednesday PM)
Marine Geology (Wednesday PM)
Small Scale Physics (Thursday AM)
Hydrothermal Processes I (Thursday AM)
Hydrothermal Processes II (Thursday PM)
Physical Processes-Models (Thursday PM)
Physical Processes (Friday AM)

Planetology
Voyager Results (Wednesday PM)
Planetary Surfaces (Thursday AM)
Icy Bodies (Thursday PM)
Venus Atmosphere I (Friday AM)
Venus Atmosphere II (Friday PM)

Seismology
Prediction and Strong Motion (Monday AM)
Seismicity and Tectonics (Monday PM)
Crustal Structure (Monday PM)
Reflection and Refraction (Tuesday AM)
Source Processes (Tuesday AM)
Seismic Source (Tuesday PM)
Earth Structure I (Wednesday AM)
Earth Structure II (Wednesday PM)
Networks and Locations (Thursday AM)
Normal Modes (Thursday PM)

Solar-Planetary Relationships: Aeronomy
Spectroscopy in Geophysics (Monday AM)
Spectroscopy in Geophysics (Monday PM)
Thermosphere (Tuesday AM)
Atmospheric Chemistry II (Tuesday PM)
Atmospheric Chemistry III (Wednesday AM)
Atmospheric Chemistry IV (Wednesday PM)
Chatanika Radar I (Thursday AM)
Chatanika Radar II (Thursday PM)
Ionospheric Irregularities (Friday AM)

Solar-Planetary Relationships: Cosmic Rays
Cosmic Rays (Monday AM)
Pioneer 10 25 Au Crossing (Tuesday PM)
Flare Composition (Wednesday AM)
Shock Acceleration (Thursday AM)

Solar-Planetary Relationships: Magnetospheric Physics
Plasma Instabilities I (Monday AM)
Plasma Instabilities II (Monday PM)
Birkeland Currents (Monday PM)
Geomagnetic Pulsations (Tuesday AM)
Auroral Phenomena (Tuesday PM)
Theory/Simulation/Expt (Tuesday PM)
Auroral Potential (Wednesday AM)
Bow Shock (Wednesday PM)
Charged Particles (Thursday AM)
VLF Effects (Thursday AM)
Magnetospheric Potpourri (Thursday PM)

SAIL INTO Baltimore

AGU Spring Meeting
May 25-29

HOTEL ACCOMMODATIONS

PARTICIPATING HOTELS	HOTEL CODE	ROOM RATES
Baltimore Hilton Hotel 101 W. Fayette St. Baltimore, MD 21201 (301) 752-1100	BHDT	Single: $43.00 Double: $58.00 Twin: $58.00
Holiday Inn-Downtown 301 W. Lombard St Baltimore, MD 21201 (301) 685-3500	HIDT	Single: $35.00 Double: $38.00 Twin: $44.00
Lord Baltimore Hotel Baltimore & Hanover Streets Baltimore, MD 21201 (301) 539-8400	LBDT	Single: $33.00 Double: $39.00 Twin: $39.00

EXTRA PERSON	PARKING
Hilton/$15.00	Hilton/nominal charge
Lord Baltimore/$8.00	Lord Baltimore/nominal charge
Holiday Inn/$7.00	Holiday Inn/free

SUITES

Hilton
- Parlor plus one bedroom suite/$125.00-$190.00
- Parlor plus two bedroom suite/$250.00

Be sure to enter the appropriate code letters on the attached form. Keep this sheet for your records, and forward the housing application form to the housing bureau at the address indicated.

All hotel reservations must be made on the housing form by April 24, 1981. No telephone requests will be accepted. Confirmations will be mailed directly to registrants by the individual hotels. After confirmation has been received, changes and cancellations should be made with the hotel directly.

Any question regarding your hotel accommodations should be made in writing to:

Housing Coordinator
AGU Spring Meeting
Baltimore Housing Bureau
1 West Pratt St.
Baltimore, MD 21201

PLEASE COPY THIS INFORMATION FOR YOUR RECORDS

American Geophysical Union
Spring 1981 Meeting

May 25–29, 1981
Baltimore, Maryland

Mail this form to:
Housing Bureau
1 West Pratt St.
Baltimore, MD. 21201

HOUSING APPLICATION FORM

READ CAREFULLY:
Please print or type (pica spaced) all information abbreviating as necessary. Confirmation will be sent by the hotel to the individual named in Part I. If more than one room is required, *this form may be photocopied.*

PART I

REQUESTOR
LAST NAME FIRST
NAME OF COMPANY OR FIRM
STREET ADDRESS OR P.O. BOX NUMBER
CITY STATE ZIP-U.S.A.
COUNTRY AREA CODE PHONE NUMBER

PART II

INSTRUCTIONS: Select *THREE* Hotel/Motels of your choice from the list of participating facilities, then enter the appropriate code letters in the boxes below.

FIRST CHOICE — HOTEL CODE
SECOND CHOICE — HOTEL CODE
THIRD CHOICE — HOTEL CODE

NOTE: Rooms are assigned in "First Come First Serve" order and if none of your choices are available, another facility will be assigned based on a referral system arranged by your convention organizer. A cut-off date is in effect and your application may not be processed if received after 14 days prior to your arrival date.

*AGU housing registration deadline is April 24, 1981

PART III

INSTRUCTIONS:
1. Select type room desired with arrival and departure dates.
2. *PRINT* or *TYPE* names of *ALL* persons occupying room.
3. If more than two people share a room, check twin and the hotel will assign two double beds.

CHECK ONE		Guest Names (Print Last Name First)
[ ] SINGLE (Room with one bed one person)	Arrival Date ____ MO DAY	1. ____
[ ] DOUBLE (Room with one bed two persons)	Departure Date ____ MO DAY	2. ____
[ ] TWIN (Room with two beds two persons)	Arrival Time ____ AM PM	3. ____
[ ] P+1 (Parlor plus one-bedroom suite)		4. ____
[ ] P+2 (Parlor plus two-bedroom suite)		
[ ] EXTRA PERSON		

IMPORTANT NOTE: Hotel *MAY* require a deposit or some other form of guaranteed arrival. If so, instructions will be on your confirmation form.

AMERICAN GEOPHYSICAL UNION
1981 SPRING MEETING

Baltimore Convention Center
Baltimore, Maryland
May 25–29

RETURN THIS FORM WITH PAYMENT TO:
Meetings Registration
American Geophysical Union
2000 Florida Ave., N. W.
Washington, D. C. 20009

Office Use
Reference Number

DEADLINE FOR RECEIPT OF PREREGISTRATION—May 8, 1981
Days you plan to attend [ ] Monday [ ] Tuesday [ ] Wednesday [ ] Thursday [ ] Friday

Registration Form

PLEASE PRINT CLEARLY

Badge Identification

NAME ON BADGE ____

AFFILIATION ____

Name ____

Mailing Address ____

Telephone # ____

Address during the meeting if different than above ____

PREREGISTRATION (rates applicable only if received by May 8 deadline)

	More than one day	One Day
Member	☐ $45	☐ $22.50
Student Member	☐ $25	☐ $12.50
Nonmember	☐ $65	☐ $32.50
Abstracts April 28 (*Eos*) $5		

SPECIAL EVENTS

Check the appropriate spaces and indicate number of reservations. — No. of tickets

AGU AWARDS RECEPTION, following open presentation ceremony; includes food and drink, 7:30 p.m., Hilton
Cost per ticket: $9.25 ____ Tuesday

SCIENCE CENTER: An evening of fun and exploration; includes food and beer, 6:30 p.m., Maryland Science Center
Cost per ticket: $6.50 ____ Thursday

SECTION LUNCHEONS

Cost of ALL LUNCHEONS, $8.00 per ticket, unless otherwise noted

Geodesy	____ Wednesday
Geomagnetism and Paleomagnetism	____ Thursday
Hydrology	____ Wednesday
Oceanography	____ Wednesday
Planetology	____ Wednesday
Seismology—cost per ticket: $3.50 due to subsidy	____ Thursday
Solar-Planetary Relationship—cost per ticket: $3.50 due to subsidy	____ Thursday
Volcanology, Geochemistry, and Petrology	____ Thursday

Please check appropriate box.
Members of the cooperating societies may register at AGU member rates
Member badges are blue on white
Nonmember badges are red on white
[ ] Member AGU [ ] Nonmember
[ ] Member cooperating society
AMS-American Meteorological Society
ASP-American Society of Photogrammetry
ACSM-American Congress on Surveying and Mapping

[ ] Payment enclosed
Charge to: [ ] Visa
[ ] Master Charge (Interbank)

Card Number ____
Interbank ____
Expiration Date ____
Signature ____

Other payments (Please identify) $____
Total $____

MAKE CHECK PAYABLE TO AGU

Office Use
Code
Check No.

MasterCard VISA

Substorm Effects (Thursday PM)
Magnetopause Effects (Friday AM)
Saturnalia (Friday AM)
SPR Data from History (Friday PM)
Saturn and Jupiter (Friday PM)

Solar-Planetary Relationships: Solar and Inter-Planetary Physics
Solar Atmosphere (Monday PM)
Solar Wind (Tuesday AM)
Solar Wind Turbulence (Thursday PM)
Flare Acceleration (Friday AM)

Tectonophysics
Hot Spots and Convection (Monday AM)
Crustal Geophysics (Monday AM)
Ocean Evolution (Monday AM)
Tectonics of Venus (Monday PM)
Illinois Deep Hole (Monday PM)
Gravity, Isostasy and Flexure (Tuesday AM)
Equation of State (Tuesday AM)
Heat Flow and Thermal Prop. (Tuesday AM)
Stress and Strain (Tuesday PM)
Non-Brittle Deformation (Wednesday AM)

Thin Skin Tectonics I (Wednesday AM)
Fracture and Faulting (Wednesday AM)
Thin Skin Tectonics II (Wednesday PM)
Subduction and Convergence (Thursday AM)
Ridges and Rifting (Friday AM)

Volcanology, Geochemistry, and Petrology
Arcs and Ophiolites (Monday AM)
Geochemistry I (Monday AM)
Geochemistry II (Monday AM)
Kimberlites (Monday PM)
Crystal Structure (Tuesday AM)
Evolution of Earth I (Tuesday AM)
Evolution of Earth II (Tuesday PM)
Experimental Petrology (Tuesday PM)
Oceanic Volcanic Rocks (Wednesday AM)
Silicate Melt Structure I (Wednesday AM)
Silicate Melt Structure II (Wednesday PM)
Isotopes (Wednesday PM)
Volcanoes-I (Thursday AM)
Volcanoes-II (Thursday PM)
Metamorphic Petrology (Thursday PM)
Plutonic Rocks (Friday AM)
VGP Potpourri (Friday AM)

GAP

Geodesy, Mapping, and Photogrammetry
Volume 19, Number 3

University of Washington, Seattle, Washington 98195) and D. K. Perovich

Absorption coefficients have been measured for bubble-free polycrystalline ice over the spectral region 400 nm to 1400 nm. In order to obtain an easily measurable attenuation at short wavelengths (400-500 nm), a 2.83 m block was used. The technique employed to grow large quantities of bubble-free ice is presented in detail. The absorption coefficients agree very well with previous results in the infrared and provide greater accuracy and finer spectral detail at visible wavelengths. (Bubble-free ice, spectral absorption, visible wavelengths.)
J. Geophys. Res., Green, Paper 1C0330

3170 Snow and ice
EFFECTS OF SOLAR ELEVATION AND CLOUDINESS ON SNOW ALBEDO AT THE SOUTH POLE
J. J. Carroll (Dept. of L.A.W.R., University of California, Davis CA 95616, U.S.A.) and B. W. Fitch

Upward and downward fluxes of shortwave radiation (0.285 < λ < 2.8 μm) measured at Amundsen-Scott Station (South Pole) during the summers of 1975, 1976 and 1977 are analyzed to determine effective surface albedos as functions of cloudiness (N) and solar elevation angle (A). For nonovercast conditions (N ≤ 0.25) the albedo decreases linearly from 0.97 at A ≤ 2° to a minimum of 0.83 ± .005 for A ≥ 20°. With near overcast conditions (N ≥ 0.7) linear decrease is also found from 0.93 at A < 2° to 0.84 ± 0.005 for A > 18°.

The nonovercast results are compared with albedos reported for other Antarctic plateau stations. The higher values at the South Pole are attributed to slower rates of surface snow metamorphosis there due to lower maximum sun elevations and absence of diurnal radiative flux and temperature cycles.

Arguments are presented to resolve conflicting reports that cloudiness both increases and decreases the snow albedo and our results show that the effect of clouds depends on the solar elevation angle.
J. Geophys. Res., Green, Paper 1C0082

3175 Soil moisture
CANOPY TEMPERATURE AS A CROP WATER STRESS INDICATOR
R. D. Jackson (U. S. Water Conservation Laboratory, 4331 E. Broadway Rd., Phoenix, Arizona 85040), S. B. Idso, R. J. Reginato, and P. J. Pinter, Jr.

Canopy temperatures, obtained by infrared thermometry, along with wet- and dry-bulb air temperatures and an estimate of net radiation were used in equations derived from energy balance considerations to calculate a crop water stress index (CWSI). Theoretical limits were developed for the canopy-air temperature difference as related to the air vapor pressure deficit. The CWSI was shown to be equal to 1 - E/Ep, the ratio of actual to potential evapotranspiration obtained from the Penman-Monteith equation. Four experimental plots, planted to wheat, received post-emergence irrigations at different times to create different degrees of water stress. [illegible]

3175 Soil moisture
A MATHEMATICAL MODEL FOR PREDICTING MOISTURE FLOW IN AN UNSATURATED SOIL UNDER HYDRAULIC AND TEMPERATURE GRADIENTS
V. Dakshanamurthy (Department of Civil Engineering, University of Saskatchewan, Saskatoon, Canada, S7N 0W0) and D. G. Fredlund

A theoretical model is proposed to predict the moisture flow in an unsaturated soil as the result of hydraulic and temperature gradients. [illegible]
Water Resour. Res., Paper 1W0248

Hydrology

[illegible]

[illegible] Water Resour. Res., Paper 1W0208

3180 Water quality
THE DEPTH OF RAINFALL-RUNOFF-SOIL INTERACTION DETERMINED BY ^{32}P
[illegible]

3180 Water quality
VARIANCE ESTIMATES FOR A DYNAMIC EUTROPHICATION MODEL OF SAGINAW BAY, LAKE HURON
[illegible]
Water Resour. Res., Paper 1W0446

3180 Water quality
COMPARISON OF FIRST-ORDER ERROR ANALYSIS AND MONTE CARLO SIMULATION IN TIME-DEPENDENT LAKE EUTROPHICATION MODELS
[illegible] For asymmetric distributions, first-order variance estimates measure variability about the typical component of the total population (i.e., the typical algal species) and Monte Carlo variance estimates measure variability of the mean component (which is more reflective of the total). One must be cognizant of these differences when estimating variance associated with model projections.
Water Resour. Res., Paper 1W0395

3180 Water quality
ANALYSIS OF NATIONAL WATER POLLUTION CONTROL POLICIES: 2. AGRICULTURAL SEDIMENT CONTROL
Leonard P. Gianessi (Resources for the Future, Inc., 1755 Massachusetts Avenue N.W., Washington, D.C. 20036) and Henry M. Peskin

Application of a national water network model permits an analysis of the likely effects of agricultural sediment control policies on the quality of the nation's waters. This analysis is believed superior to previous assessments based mainly on erosion estimates without accounting for the characteristics of the receiving water or the contribution of pollutants from nonagricultural activities. Specifically, while the earlier assessments concluded that agriculturally-related pollution problems are widespread and ubiquitous, this analysis concludes that it is probably more efficient to focus sediment-related pollution control policies on about one-third of the nation's agricultural regions. (Pollution, agricultural pollution, sediment control, water quality model, policy analysis)
Water Resour. Res., Paper 1W0110

3180 Water quality
COMMUNITY EVALUATION OF ADOPTED USES OF RECLAIMED WATER
W. H. Bruvold (School of Public Health, University of California, Berkeley, CA 94720)

One hundred and forty residents of Irvine, California were interviewed to assess their knowledge, evaluation and recommendations regarding the use of reclaimed water in their community for an ornamental lake, for golf course irrigation, for agricultural irrigation, for park and playground irrigation and for common residential lawn irrigation. Additionally, their attitudes toward future use of reclaimed water for drinking, not presently planned for Irvine, were also assessed. Results showed that more than half of the respondents were generally aware of reclamation in Irvine, but more than half were not aware of the details involved. Once specific uses were outlined for the less informed, the responses of all respondents to the specific reclamation and reuse projects now underway in Irvine were very positive. Most respondents recommended continuing existing uses rather than expanding or reducing the current reclamation project. Further, most respondents were not in favor of using reclaimed water for drinking in the future. The Irvine findings confirm earlier more general findings that indicate that the public will accept moderate contact uses of reclaimed water in their own community and it is recommended that reclamation projects be initiated in this manner. (Reclaimed water, attitudes, adoption, public policy).
Water Resour. Res., Paper 1W0087

Meteorology

3710 Boundary layer structure and processes
WIND-WATER TUNNEL SIMULATION OF SMALL-SCALE OCEAN ATMOSPHERE INTERACTIONS
[illegible]
J. Geophys. Res., Green, Paper 1C0245

3710 Boundary layer structure and processes
PLANE WITH PROTRUSIONS AS AN ATMOSPHERIC BOUNDARY
[illegible]

3715 Chemical composition and chemical interactions
EFFECT OF NITRAPYRIN ON EMISSION OF NITROUS OXIDE FROM SOIL FERTILIZED WITH ANHYDROUS AMMONIA
[illegible] was reduced 83% by addition of nitrapyrin at the rate of 0.56 kg ha^{-1}. The corresponding reduction when nitrapyrin was added to anhydrous ammonia applied in the spring was 87%. These observations indicate that nitrapyrin has potential value for reduction of the N_2O emissions induced by nitrogen fertilization of soils.
Geophys. Res. Lett., Paper 1L0321

3715 Chemical composition and chemical interactions
ESTIMATING THE OZONE BUDGET IN THE BOUNDARY LAYER BY USE OF AIRCRAFT MEASUREMENTS OF OZONE EDDY FLUX AND MEAN CONCENTRATION
D. H. Lenschow (National Center for Atmospheric Research, Boulder, CO 80307) R. Pearson, Jr. and B. B. Stankov

A fast response chemiluminescent ozone sensor was mounted in an NCAR Queen Air aircraft instrumented for air motion, temperature and humidity measurements. The vertical flux of ozone was then obtained by the eddy correlation technique for several flights in the daytime atmospheric boundary layer over eastern Colorado. Because of the range and mobility of the aircraft, this technique can be utilized for a wide variety of situations. For example, a flight leg over an interstate highway shows large negative fluctuations in O_3 due to vehicular emission of NO which are well-correlated with positive temperature and vertical velocity fluctuations. On one flight, the significant terms in the mean ozone concentration budget (and also, for comparison, the sensible heat and humidity budgets) were evaluated from the airplane measurements. For this flight, which occurred under clear skies over range and crop land about 100 km northeast of Denver, the time rate of change of ozone density in the lower half of the boundary layer was about 2.4 ng m^{-3}s^{-1}. This was several times larger than the contributions by horizontal advection and the divergence of the vertical eddy flux of ozone. Thus, most of the observed increase in ozone concentration must have been the result of internal photochemical production of ozone. This may be the first well-documented example where the rate of O_3 increase with time is shown to be balanced by photochemical production of O_3. The deposition velocity of ozone for this case was about 0.47 cm s^{-1}
J. Geophys. Res., Green, Paper 1C0441

3715 Chemical composition and chemical interactions
A COMPARISON OF OZONE MEASUREMENTS
K. Mauersberger (School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455) R. Finstad, S. Anderson, and D. Robbins

A mass spectrometer beam experiment and a UV absorption instrument (modified Dasibi instrument) have simultaneously measured ozone mixing ratios in the stratosphere (20-40 km). Both experiments were independently calibrated using absolute standards. The ozone profiles obtained during three balloon descents are in excellent agreement; fine structures are resolved by both experiments. The RMS uncertainty in ozone mixing ratios is about 3% for either instrument.
Geophys. Res. Lett., Paper 1L0445

3715 Chemical composition and chemical interactions
BACKGROUND NO_x MIXING RATIOS IN AIR MASSES OVER THE NORTH ATLANTIC OCEAN
[illegible]
J. Geophys. Res., Green, Paper 1C0495

3715 Chemical composition and chemical interactions
DIURNAL ANALYSIS OF LOCAL VARIABILITIES IN STRATOSPHERIC NO_2
[illegible] resolution are achieved in observations. (NO_2, column density, photochemical models, stratosphere, diurnal variability, trace species in the atmosphere).
J. Geophys. Res., Green, Paper 1C0140

3740 General circulation
MONTHLY AND SEASONAL VARIABILITY IN THE OCEAN-ICE-ATMOSPHERE SYSTEMS OF THE NORTH PACIFIC AND THE NORTH ATLANTIC
J. E. Walsh (Laboratory for Atmospheric Research, University of Illinois, Urbana, Illinois 61801) and J. E. Sater

Four regional indices of sea ice variability and thirty years of monthly sea surface temperature (SST) and sea level pressure (SLP) data are used to evaluate the large-scale interactions within the ocean-ice-atmosphere systems of the North Pacific and the North Atlantic. A direct association between positive (negative) SST anomalies and light (heavy) ice in the Bering Sea is indicated. The SST/ice coupling in the northern Alaskan waters is also statistically significant. The SST anomalies in both the North Pacific and the North Atlantic appear as persistent responses to atmospheric forcing. The SLP distributions over both oceans correlate significantly with the arctic SLP distribution, although the midlatitude atmospheric circulation shows no systematic tendency to lead or lag the arctic circulation. Sea ice fluctuations correlate most highly with the atmospheric forcing over antecedent periods of approximately 9 months in the northern Alaskan waters, [illegible] months in the Bering Sea, and 5-7 months in the East Greenland Sea. The strength of the 9-month mean onshore airflow component describes over 70% of the northern Alaskan ice variance. (Atmospheric circulation, sea ice, ocean [illegible]
[illegible]

3740 General circulation
NORMAL MODE INITIALIZATION
Roger Daley (National Center for Atmospheric Research, P.O. Box 3000, Boulder, Colorado)

The baroclinic primitive equation models used for short and medium range weather forecasting admit undesirable high frequency gravity waves. The gravity waves are excited by initial imbalances between the observed wind and mass fields and by inconsistencies between model and atmosphere. Over the years, many initialization techniques have been devised to balance the initial state, but without notable success. The recent introduction of normal mode initialization techniques has, to a large degree, solved the problem. The present review will discuss the development of the technique from first principles, introduce the slow manifold concept and discuss successful applications and remaining problems.
Rev. Geophys. Space Phys., Paper 1R0315

3755 Interaction of atmosphere with electromagnetic waves
OBSERVATIONS OF CLEAR AIR TURBULENCE AND WINDS WITH THE MILLSTONE HILL RADAR
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The Millstone Hill 440 MHz radar at Westford, Massachusetts has been upgraded for studies of turbulence and winds in the troposphere and lower stratosphere. Useful data have been obtained up to 20 km altitude. The radar has been operated with a peak pulse power of 1-1.5 MW, a pulse length of 10 μsec and a pulse repetition of 500 Hz. The 150 foot diameter steerable antenna has been used differently in three types of experiments, (a) Antenna azimuth scans with fixed elevation, (b) elevation scan with fixed azimuth and (c) fixed antenna.

Azimuth scan experiments can obtain both the horizontal and vertical wind components. Antenna elevation scans have been used to investigate the horizontal structure of turbulence. The fixed antenna experiments provide maximum resolution and are useful for studying the occurrence of waves.

Waves in both the velocity and C_n^2, the refractive index turbulence structure constant, have been frequently observed at heights near the tropopause and below. The waves have periods 10-20 minutes and have been interpreted as internal gravity waves. The largest amplitude waves have been found to occur (1-2 km) below the level of a velocity shear. Waves generally persist for several cycles.

Using antenna elevation scan method the level of turbulence (as measured by the C_n^2 value) has been measured at points separated by 10-20 kms. Horizontal patches of turbulence have been found that appear to move with the wind.
J. Geophys. Res., Green, Paper 1C0391

3770 Particles and Aerosols
ON THE ROLE OF PHOTO-INDUCED SOLUTION REACTIONS IN DETERMINING ATMOSPHERIC AEROSOL CONCENTRATIONS
P. Middleton, (National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307)

The role of photo-induced solution reactions in determining atmospheric aerosol concentrations is discussed and investigated with theoretical estimates. The main photo-induced solution reaction considered is the conversion of dissolved O_3 into H_2O_2 which can then react with dissolved SO_2 and NO_2 to form sulfate and nitrate. The rate of this reaction is compared to the rate of H_2O_2 formation in solution from diffusion and absorption of H_2O_2 gas to the aerosol surface. The influences of H_2O_2 concentration and aerosol size on the relative rates are investigated. It is found that the photo-induced solution reaction rate is much lower than the gas diffusion rate but becomes more competitive as particle size increases. (Aerosols, solution photochemistry, H_2O_2, sulfate, nitrate).
J. Geophys. Res., Green, Paper 1C0333

Mineralogy, Petrology, and Crystal Chemistry

4230 Experimental mineralogy and petrology
PHASE RELATIONSHIPS OF S-TYPE GRANITE WITH H_2O TO 35 KB. MUSCOVITE GRANITE FROM HARNEY PEAK, SOUTH DAKOTA
[illegible] partial fusion of pelitic rocks between about 20 km and 40 km depth given sufficient H_2O, and subcrystal muscovite or sillimanite from the source rocks. The phase relationships are consistent with the idea of S-type granites, but not sufficient to prove the origin of this rock. Additional tests require phase relationships of other associated granitic rocks, and details of geochemistry, geophysics, and field relationships.
J. Geophys. Res., Red, Paper 1B0494

4260 Paragenesis, petrography, and petrogenesis
THE REDSKIN GRANITE--EVIDENCE FOR THERMOGRAVITATIONAL DIFFUSION IN A PRECAMBRIAN GRANITE BATHOLITH
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The 1000 m.y.-old composite Pikes Peak batholith consists largely of medium- to coarse-grained biotite granite, but is intruded by several smaller granite plutons. Two of these, the Tarryall Mountains batholith and the Redskin Granite, are here interpreted as cupolas atop the main mass of the Pikes Peak batholith.

Chemical analyses for 38 elements in rocks from the Redskin Granite, the Tarryall Mountains batholith, and the biotite granite of the Pikes Peak batholith support the contention that the compositions of the smaller plutons are unlikely to have evolved from that of the main mass of the batholith by crystal fractionation. It is believed that these compositions arose through liquid-state fractionation processes, possibly the convection-aided thermogravitational model of Shaw and others (1976).

It is important to recognize that the chemical signature of this fractionation process can be discerned in holocrystalline rocks, as well as their glassy equivalents, because the process may be instrumental in the formation of some kinds of lithophile ore deposits. (Granite, thermogravitational diffusion, ore deposits)
J. Geophys. Res., Red, Paper 1B0493

4260 Paragenesis, petrography, and petrogenesis
THE LATE-ARCHAEAN QÔRQUT GRANITE COMPLEX OF SOUTHERN WEST GREENLAND
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Granites and granite pegmatites comprising the ca. 2550 Ma Qôrqut granite complex occur in a SSW-NNE-trending linear belt >150 km long extending through the Buksefjorden - Ameralik - Godthåbsfjord region of southern West Greenland. The main body of the complex crops out over a distance of 50 km from Ameralik to Kapisigdlit Kangerdluat and reaches a maximum outcrop width of 18 km between Storø and Qôrqut. Around Qôrqut, the complex comprises 3 main groups of granites: early leucocratic granites; various grey biotite granites; and late aplogranite - granite pegmatites. Within the 1500m vertical section available in this area the complex has a tripartite structure comprising a Lower Zone dominantly of polyphase granite, an Intermediate Zone where country rock occurs as rafts in polyphase granite with a complex sheeted structure, and an Upper Zone dominantly of country rock sheeted by granite. 52 specimens of granite have been analysed for major, minor and some trace elements. Geochemical variation within the complex is consistent with either fractional crystallisation or partial melting, but in both cases feldspar + biotite must have been involved either as fractionating phases or as residual phases after melting to account for the trace element chemistry. Two possible models for the generation of the complex are: either anatexis of granulite facies rocks in the lower crust following an influx of volatiles and heat from the mantle; or melting at intermediate depths of amphibolite facies rocks with volatiles supplied by breakdown of hydrous phases. (Granite, geochemistry, anatexis, Greenland).
J. Geophys. Res., Red, Paper 1B0461

4270 Properties of minerals
MAJORITE: VIBRATIONAL AND COMPRESSIONAL PROPERTIES OF A HIGH PRESSURE PHASE
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Majorite, the garnet-structured high-pressure phase of pyroxene, has been characterized by infrared (IR) spectroscopy, and X-ray diffraction between 0 and 8 GPa (80 kbar). In this structure, three out of four (Mg,Fe) are in eightfold coordination and one out of four Si is in sixfold coordination. The IR spectrum indicates the existence of large tetrahedral distortions, probably associated with the small cation radii (significant anion-anion interactions). For a sample corresponding approximately to $(Mg_{0.79}Fe_{0.21})SiO_3$ the lattice parameter and density are a = 1154.4(±0.1) pm and ρ = 3.737 (±0.003) Mg/m^3. Hydrostatic compression measurements yield a zero-pressure bulk modulus and its pressure derivative of K_0 = 221(±15) GPa and K_0' = 4.4(±4.8). The composition-dependent volume and bulk modulus in the system pyrope-almandine-majorite are well constrained by the present data: for majorite, these are substantially smaller and larger, respectively, than predicted by systematics for garnets. Elasticity systematics largely fail to account for the moduli of garnets, although Anderson's seismic equation of state provides a satisfactory correlation. In transforming to higher pressure phases beyond majorite (with substantially higher densities), pyroxene does not exhibit significant increases in bulk sound velocity. Transformation to majorite probably occurs within the upper mantle and further phase transitions in pyroxene may be difficult to observe seismologically.
J. Geophys. Res., Red, Paper 1B0492